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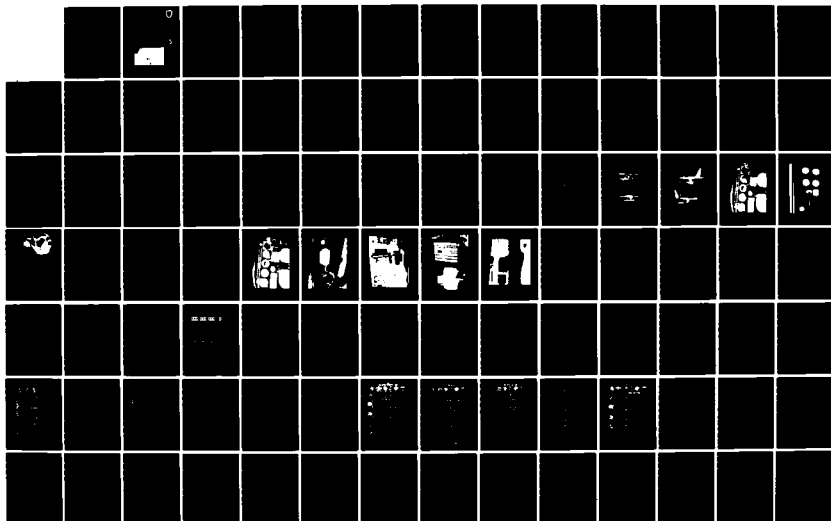
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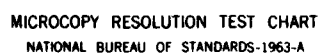
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USAAEFA PROJECT NO. 84-04



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PRELIMINARY AIRWORTHINESS EVALUATION OF THE RUTAN AIRCRAFT FACTORY (RAF), INC. LONG - EZ AIRPLANE WITH EXTERNAL SIGHT

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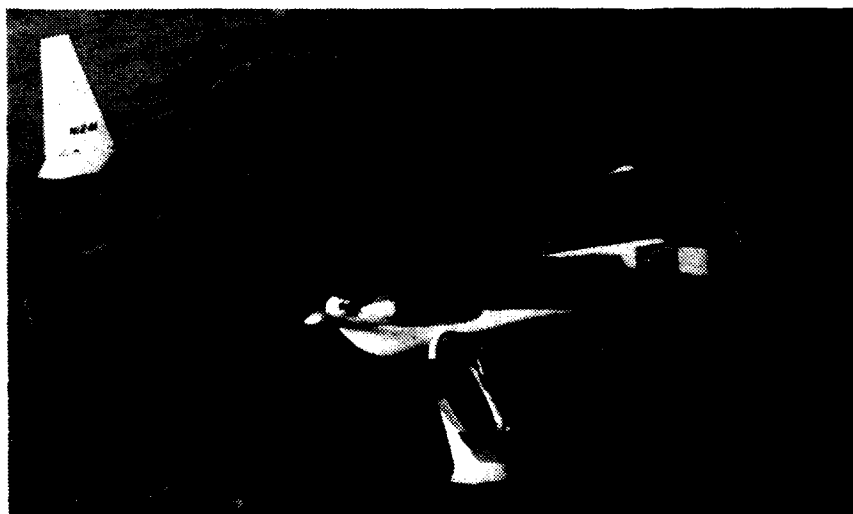
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MAY 1984

FINAL REPORT

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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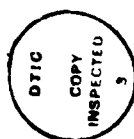
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The US Army Aviation Engineering Flight Activity conducted a Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory, Inc. designed LONG-EZ airplane with an external sensor (Combat Surveillance Airborne Test Bed (CSATR) configuration), from 12 March through 10 April 1984 at Edwards Air Force Base, California. During the test program 13 flights were conducted for a total of 15.3 hours, of which 11.6 were productive. The objectives of the evaluation were to assess the performance and handling qualities of the LONG-EZ so that		

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the US Army Aviation Systems Command could issue an airworthiness release to allow the 9th Infantry Division to conduct a mission evaluation of the CSATB configured aircraft. All tests were performed at an average gross weight of 1335 pounds and nominal mission longitudinal center of gravity (cg). Test results were compared with basic data obtained during previous testing and evaluated against military specification MIL-F-8785C. The performance was degraded considerably by the installation of the external sensor with handling qualities at the mid cg essentially identical to those obtained near the aft cg limit, FS 104.0, for the basic aircraft. The performance capabilities and handling qualities, however, are adequate for for the CSATB evaluation including night operations. There were no new deficiencies and one additional shortcoming identified during this evaluation. A previously reported shortcoming of limited directional control has been eliminated by the increase in rudder area in the CSATB configured LONG-EZ aircraft.

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DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

REPLY TO
ATTENTION OF

DRSAV-ED

SUBJECT: Directorate for Engineering Position of the Final Report of USAAEFA Project No. 84-04, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc., LONG-EZ Airplane with External Sight

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1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The report documents the flight test results of the Rutan Aircraft Factory (RAF) LONG-EZ aircraft with a mockup installation of an external FLIR sensor. This was the third evaluation in a series of three which were conducted by the US Army Aviation Engineering Flight Activity (USAAEFA). The two previous evaluations were conducted in the clean configurations (no FLIR sensor) under USAAEFA Projects 82-18, "Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc., LONG-EZ Airplane" and 83-18, "Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory, Inc., LONG-EZ Airplane (S/N 1241)". Based on the results of the two evaluations, the 9th Infantry Division (9th ID) was issued Airworthiness Releases for the conduct of special mission concept evaluations. As a result of the recent evaluation by the USAAEFA, the 9th ID was issued an Airworthiness Release for the LONG-EZ Airplane with a FLIR sensor for continued special mission concepts evaluations.

2. The Directorate for Engineering agrees with the subject report Conclusions and Recommendation and the following additional comments are provided. Comments are directed to the report paragraphs as indicated.

a. Paragraph 46. The potential for loss of directional control due to a single point brake failure during takeoff/landing and ground handling was identified as a deficiency in the two previous evaluations. The LONG-EZ is currently being used only for conceptual evaluations under an Airworthiness Release and there is no intent to release the airplane operationally at this time. Consequently, continued operations under the Airworthiness Release is acceptable. However, if the LONG-EZ is to be type classified or used operationally, then correction of this deficiency is mandatory.

b. Paragraph 47. The objectionable internal light reflections of the landing light on the canopy has a direct impact on the pilot performance and could distract his attention during critical takeoff/landing maneuvers. Consequently, it is considered a shortcoming that must be corrected prior to type classification or operational use. It appears this type of problem can be easily corrected.

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c. Paragraph 48. While the LONG-EZ airplane met all the requirements of MIL-F-8785C, except for the unaccelerated stall warning characteristics, there is no requirement for such compliance. This characteristic remains a short-coming which is not considered essential to correct by aerodynamic correction of installation of a stall warning system because of the docile stall characteristics.

3. The results of the USAAEFA flight evaluation, contractor flight testing and evaluation of contractor analyses and reports of the LONG-EZ airplane with the FLIR sensor by the Directorate of Engineering provide the basis for issuance of the Airworthiness Release to the 9th ID for continued conceptual testing. When operated within the restrictions and limitations of the Airworthiness Release, the LONG-EZ airplane can be safely flown for the 9th ID evaluations.


RONALD E. GORMONT
Acting Director of Engineering

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INTRODUCTION

BACKGROUND

1. The LONG-EZ is a small, lightweight airplane designed by the Rutan Aircraft Factory (RAF), Inc. The airplane is a home-built, experimental class aircraft certified under Federal Air Regulation Part 21 (ref 1, app A) of the Federal Aviation Administration. It is intended to be built according to the LONG-EZ manufacturing manual by private construction with materials and prefabricated parts obtained from commercial sources. The Army's interest in the aircraft is exploratory for missions as yet not defined. Two airplanes were assembled by the 9th Infantry Division (9th ID) at Fort Lewis, Washington, and evaluated in a clean configuration during US Army Aviation Engineering Flight Activity (USAAEFA) Projects No. 82-18 and 83-18 (refs 2 and 3, app A). The California Institute of Technology, Jet Propulsion Laboratory (JPL) was under government contract to modify LONG-EZ aircraft, US Army Serial Number (S/N) 1241 to the Combat Surveillance Airborne Test Bed (CSATB) configuration in support of 9th ID evaluations. The structural modification was performed by RAF under JPL contract and included the installation of a forward looking infrared (FLIR) sensor. Additional modifications requested by the 9th ID included the addition of a landing light, modification of the instrument panel and an increase in rudder area. USAAEFA was tasked by the US Army Aviation Systems Command (AVSCOM) (ref 4, app A) to conduct a Preliminary Airworthiness Evaluation (PAE) on the performance and handling qualities of the CSATB configuration LONG-EZ aircraft, S/N 1241.

TEST OBJECTIVES

2. The objectives of the evaluation were to obtain quantitative and qualitative flight test data on performance and flying qualities necessary for AVSCOM to prepare an airworthiness release to allow the 9th ID to conduct mission evaluations of the CSATB configured LONG-EZ aircraft.

DESCRIPTION

3. The test vehicle designed by RAF and constructed by the 9th ID according to the LONG-EZ manufacturing plans is a two place, tandem seat, home-built, experimental class aircraft. Unique features include composite construction, a nose mounted canard for pitch control, and a mid-mounted, high aspect ratio, swept wing featuring an Eppler airfoil and tip mounted winglets. The airplane also features tricycle landing gear (with a retractable nose wheel) and a landing airbrake (belly mounted "speed brake").

Propulsion is provided by a rear mounted, four cylinder, Lycoming O-235-L2C reciprocating engine and a fixed pitch wooden propeller. Modifications to the basic configuration include a belly mounted FLIR sensor, increase in rudder surface area, and relocated and enlarged engine ram air inlets. A mock-up external FLIR sensor identical in weight and size was used for this test. Other changes include a landing light, additional avionics, and rear-ranged cockpit instruments. Further description of the aircraft is presented in appendix B and a more detailed description of the LONG-EZ is contained in the owner's manual (ref 5, app A).

TEST SCOPE

4. A limited performance and handling qualities evaluation of the CSATB configured LONG-EZ was conducted at Edwards Air Force Base, California (2302 foot field elevation). The evaluation was conducted from 12 March through 10 April 1984. During the test program 13 flights were conducted for a total of 15.3 hours, of which 11.6 were productive. Test results were compared with baseline data obtained during previous testing (refs 2 and 3, app A). A qualitative evaluation was also conducted to determine aircraft suitability for night flight. Flight restrictions and operating limitations contained in the airworthiness release issued by AVSCOM (ref 6, app A) were observed during the evaluation. The airplane configurations are presented in table 1 with the test conditions shown in tables 2 and 3.

TEST METHODOLOGY

5. Established flight test techniques and data reduction procedures were used during this test program (refs 7 and 8, app A). The test methods are described briefly in the Results and Discussion section of this report. Flight test data were automatically recorded on ground based magnetic tape via telemetry. A list of the test instrumentation is contained in appendix C. Test techniques (other than the standard techniques described in appropriate references), weight and balance, and data reduction techniques are contained in appendix D. A Handling Qualities Rating Scale (HORS) (fig. 1, app D) was used to augment pilot comments relative to the aircraft handling qualities. Deficiencies and shortcomings are in accordance with the definitions presented in appendix D.

Table 1. Airplane Configurations¹

Configuration	Nose Gear Position	Power Setting
Takeoff (TO)	down	TO ²
Climb (CL)	up	MCP ²
Cruise (CR)	up	PLF ³
Power Approach (PA)	up	PNA ⁴
Landing (L)	down	IDLE
Glide (G)	up	IDLE

NOTES:

¹Landing airbrake retracted in all configurations

²Takeoff and maximum continuous power: maximum brake horsepower (BHP) available, (rated at 118 BHP at 2800 engine RPM, sea level standard day, full rich mixture), or full throttle.

³Power for level flight: BHP required to maintain level flight, peak exhaust gas temperature (EGT) mixture.

⁴Power for normal approach: BHP required to maintain 3-degree glide angle.

Table 2. Test Conditions

Test	Average Gross Weight ¹ (lb)	Conditions			
		Average Longitudinal CG Location ² (in.)	Density Altitude (ft)	Trim Calibrated Airspeed (KCAS)	Configuration
Airspeed Calibration	1330	100.2	4000-5640	81 - 150	TO, CL, CR, PA, L
Takeoff Performance	1340	100.9	2700	54 - 71	TO
Level Flight Performance	1325	100.8	7175-12,112	64 - 78	G,L
Landing Performance	1340	100.9	2700	59 - 77	L
Stall Characteristics	1330	100.2	7135-8120	63 - 80	TO, CL, CR PA, L
Control Positions in Trimmed Forward Flight	1330	100.6	4000-5640	81 - 150	CL, CR, PA
Static Longitudinal Stability	1335	100.1	4600-7300	95, 97, 105	CL, CR, L
Static Lateral-Directional Stability	1330	100.8	4690-7200	94, 96, 103, 116	CL, CR, L
Maneuvering Stability	1330	100.2	5800-8000	92 - 140	CR
Dynamic Stability	1335	100.8	4000-7480	95 - 122	CR
Roll Control Effectiveness	1335	100.2	7200-7500	100	CR
Vibration Characteristics	1330	100.2	4000-5640	81 - 150	TO, CL, CR, PA, L
Night Evaluation	1345	100.9	2700-5100	0 - 150	TO, CL, CR PA, L

NOTES:

¹Normal maximum gross weight: 1325 lb. Alternate maximum gross weight: 1425 lb (takeoff only).

²Center of gravity (cg) range: FS 97 to 104

RESULTS AND DISCUSSION

GENERAL

6. Performance and handling qualities of the CSATB configured LONG-EZ aircraft were evaluated under the conditions and configurations listed in tables 1 and 2. All tests were performed at an average gross weight of 1335 pounds and nominal mission longitudinal center of gravity (cg), fuselage station (FS) 101.0 (mid). The FLIR sensor was ballasted to the representative system weight and moments of inertia. Test results were compared with baseline data (refs 2 and 3, app A) obtained during previous testing and evaluated against military specification MIL-F-8785C (ref 9, app A). The performance was degraded considerably by the installation of the FLIR sensor with handling qualities at the mid cg essentially identical to the those obtained near the aft cg limit, FS 104.0, for the basic aircraft. The performance capabilities and handling qualities, however, are adequate for the CSATB evaluation including night operations. There were no new deficiencies and one additional shortcoming identified during this evaluation. A previously reported shortcoming of limited directional control has been eliminated by the increase in rudder area in the CSATB configured LONG-EZ aircraft. The previously reported deficiency of loss of directional control due to single point brake failure during takeoff/landing and ground handling, although improved by the increase in rudder area, remains a deficiency.

PERFORMANCE

General

7. The performance capabilities of the CSATB configured LONG-EZ airplane were evaluated to provide data for comparison with and as a supplement to baseline data obtained during previous testing (refs 2 and 3, app A). All tests were conducted at an average gross weight of 1335 pounds and at the nominal mission cg, FS 101.0 (mid). Test conditions are outlined in table 2 and data analysis techniques are contained in appendix D. The performance was degraded considerably by the installation of the FLIR sensor.

Takeoff Performance

8. Takeoff tests were performed at the conditions listed in table 2. Takeoffs were conducted from a level dry concrete runway by aligning the aircraft on centerline of the runway with the nose wheel straight. Full power was applied prior to releasing the brakes. The initial rotation speed and liftoff airspeeds were

determined by maintaining full aft longitudinal control until nose wheel liftoff and then adjusting longitudinal control to maintain the canard upper surface level on the horizon (approximately 12 degrees of pitch) until takeoff was achieved. On subsequent takeoffs, rotation speed was then incrementally increased to the point where rotation to a 12 degree pitch attitude resulted in a simultaneous takeoff. Predetermined climb airspeeds were maintained until 100 feet above the ground and then adjusted to a normal cruise climb airspeed of 90 knots indicated airspeed (KIAS). Ground roll and simulated obstacle clearance distances were determined by use of runway ground observers and a visual theodolite. The best takeoff performance was obtained using a rotation speed of 65 KIAS, liftoff at 63 KIAS, and climb at 65 KIAS at the maximum gross weight (1325 lb). At this condition the minimum ground roll was approximately 2100 feet. This was approximately 75 percent longer ground roll than takeoff performance data presented in the operator's manual (ref 5, app A) or obtained during previous testing (refs 2 and 3, app A) for the baseline aircraft. Qualitative estimate of the minimum incremental distance required to attain a 50 foot obstacle clearance height after liftoff while climbing at 65 KIAS is 800 feet at a maximum gross weight of 1325 lb.

9. Analysis of data obtained during the takeoff roll showed a simultaneous decrease in indicated airspeed (typically 3 to 6 knots) and pressure altitude (typically 50 feet) with aft stick application which would indicate a static port position error change. The apparent static port position error change coincident with rotation, which resulted in an abrupt decrease in indicated airspeed, had no measurable effect on the takeoff performance. The following note should be incorporated in the operator's manual.

NOTE

An abrupt decrease in both indicated airspeed (typically 3 to 6 knots) and pressure altitude (approximately 30 feet) will occur coincident with rotation due to an apparent static port position error change.

Level Flight Performance

10. The zero thrust glide test method was used to determine the drag difference between the CSATB configured LONG-EZ aircraft and the basic aircraft (ref 2, app A). The test aircraft was stabilized and trimmed (ball centered) at incremental airspeeds from 59 knots calibrated airspeed (KCAS) to 106 KCAS in a descent

in both the glide and landing configuration with the engine and propeller stopped through a target pressure altitude band of 10,000 to 6,000 feet. Comparative results are presented in figure 1, appendix E. Modification of the basic airframe to the CSATB configuration (with the FLIR sensor installed) resulted in an equivalent flat plate area (F_e) increase of 2.09 square feet in the cruise configuration and 0.76 square feet for the landing configuration.

11. The level flight performance capabilities of the CSATB configured LONG-EZ aircraft were determined by computing power required as a function of airspeed. Thrust horsepower (THP) was calculated from the glide drag polar (fig. 1, app E). A comparison of the level flight performance capabilities between the CSATB configured LONG-EZ and the baseline aircraft for a nominal mission gross weight (1300 lb) at standard day, sea level conditions is presented in figure A. Comparatively, at 80 THP, the level flight airspeed of the CSATB configured LONG-EZ aircraft was approximately 117 knots true airspeed (KTAS) versus 145 KTAS for the basic aircraft in the cruise configuration. With the FLIR sensor installed on the CSATB configured LONG-EZ aircraft, the F_e increase of 2.09 square feet (cruise configuration) reduces considerably the level flight speed capability of the aircraft by approximately 30 KTAS.

Stall Performance

12. Stall performance was evaluated at the conditions and aircraft configurations listed in table 2. The aircraft was trimmed at 1.2 stall airspeed. Airspeed was then decreased at approximately 1 knot per second until achieving a stall. Typical time histories of the stall characteristics are presented in figures 2 through 9, appendix E. Table 3 shows stall airspeeds for the various aircraft configurations and loadings. The stall airspeeds for the CSATB configured aircraft were essentially unchanged from the basic aircraft.

Landing Performance

13. Landing performance evaluations were conducted concurrently with the takeoff performance tests listed in table 2. Landing approaches were made at a constant airspeed from 75 to 60 KTAS in five knot increments with power required to maintain a final descent path of approximately 3 degrees to a predetermined touchdown point. After touchdown on the main wheels, the nose wheel was lowered to the ground immediately with maximum braking applied to smoothly and rapidly stop the aircraft in a straight line. The best landing performance at the maximum gross weight

FIGURE A
LEVEL FLIGHT PERFORMANCE COMPARISON
LONG-EZ USA S/N 82-1241 (N1241)

GROSS WEIGHT = 1300 POUNDS
 PRESSURE ALTITUDE = SEA LEVEL
 AMBIENT TEMPERATURE = 15.0 DEG C

- NOTES: 1. CLEAN AIRCRAFT DATA OBTAINED FROM
 USAAEFA PROJECT NO. 82-18, "PRELIMINARY
 AIRWORTHINESS EVALUATION OF THE RUTAN
 AIRCRAFT FACTORY (RAF), INC, LONG-EZ
 AIRPLANE", DATED JUNE 1983, FINAL REPORT.
 2. FLIR CONFIGURED AIRCRAFT DATA OBTAINED
 FROM FIG. 1, APP. E.

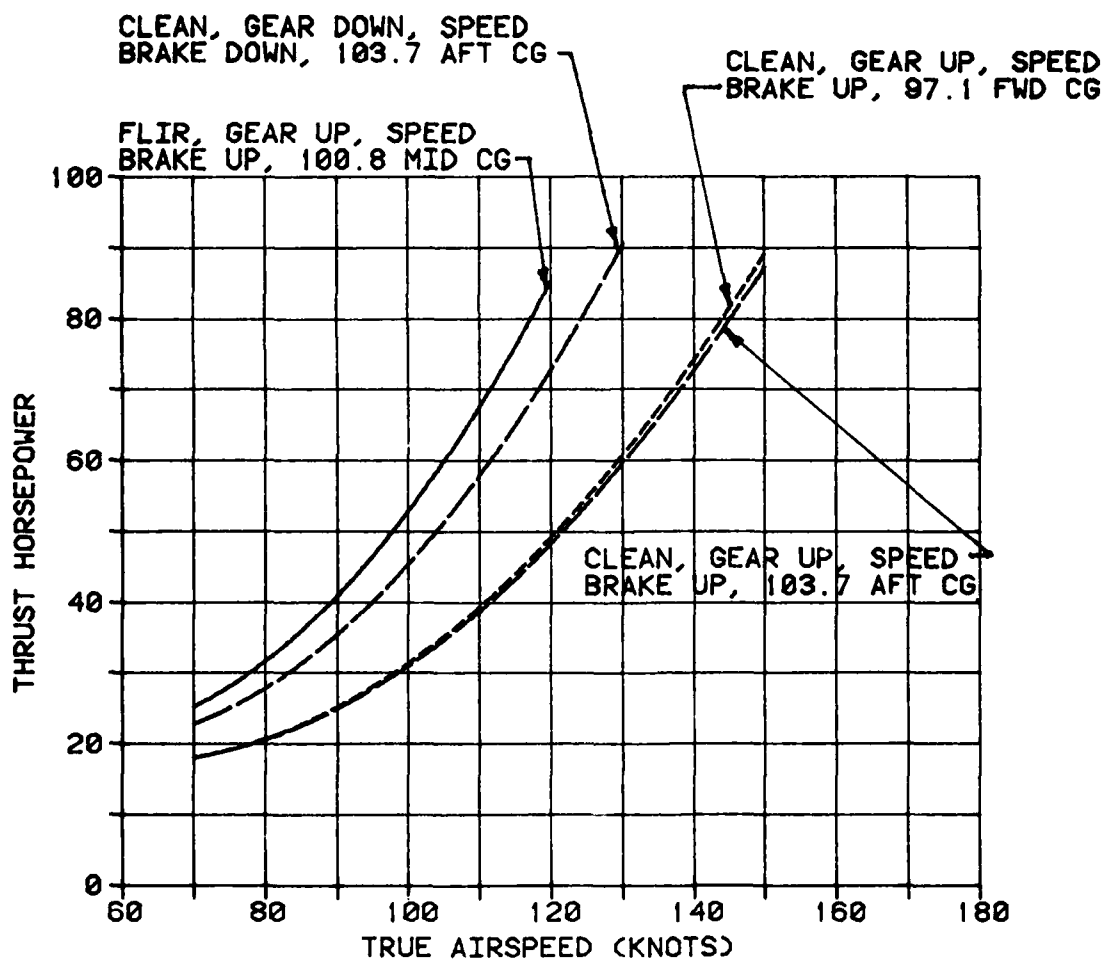


Table 3. Stall Performance

Configuration	Gross Weight (lb)	Center of Gravity (FS)	Density Altitude (ft)	Outside Air Temperature (°C)	Bank Angle (deg)	Indicated Stall Airspeed (kts)
Takeoff	1320	100.1	8200	-2.0	0	51
Climb	1320	100.1	7920	-1.0	0	52
Cruise	1320	100.1	7820	-0.5	0	52
Glide	1330	100.1	7820	-0.5	0	51
Landing	1320	100.1	7740	-1.0	0	52
Cruise	1320	100.1	7500	-0.5	51L	63
Landing	1320	100.1	7300	0.0	45L	60

of 1325 lb was obtained during approaches made at 70 KIAS with a touchdown airspeed of 61 KIAS. At this condition the ground roll distances ranged from 805 to 910 feet. The landing performance capabilities of the CSATB configured LONG-EZ compared favorably with previously obtained results for the basic aircraft.

HANDLING QUALITIES

General

14. A limited handling qualities and pilot workload evaluation of the CSATB configured LONG-EZ was conducted to determine stability and control characteristics at the test conditions listed in table 2. Emphasis was placed on operation at the maximum mission gross weight of 1325 pounds and nominal mission cg, FS 101.0 (mid). All coordinated flight maneuvers were flown in trimmed (ball-centered) flight. Where applicable, the test results were compared with basic data obtained during previous testing (refs 2 and 3, app A). Handling qualities at the mid cg were essentially identical to those obtained near the aft cg limit, FS 104.0, for the basic aircraft, and therefore, the aft cg should be limited to FS 101.5 for the CSATB configured aircraft. The roll oscillations in light to moderate turbulence were not noticeably different with the FLIR sensor installed than previously reported with extension of the landing gear and speed brake (ref 2, app A). A previously reported shortcoming of limited directional control has been eliminated by the increase in rudder area in the CSATB configured LONG-EZ aircraft. The previously reported deficiency of loss of directional control due to single point brake failure during takeoff/landing and ground handling although improved by the increase in rudder area remains a deficiency.

Control Positions in Trimmed Forward Flight

15. Control positions in forward flight were evaluated from 76 to 148 KCAS in conjunction with the airspeed calibration test at the conditions shown in table 2. The variation of control positions and pitch attitude with airspeed is shown in figures 10 and 11, appendix E, and are essentially unchanged to those obtained near the aft cg limit for the basic aircraft. The longitudinal control position variation with airspeed in level flight was conventional, in that increasing forward stick position was required with increasing airspeed. The lateral and directional control positions did not change with airspeed. Pitch attitude varied from 11 degrees nose up at 81 KCAS in the climb configuration to 10.5 degrees nose down at 149 KCAS in the cruise configuration during diving flight. Control margins at all airspeeds

exceeded 35 percent. These characteristics decreased pilot workload to accurately attain a desired airspeed within 3 knots (MORS 3). The control positions in trimmed forward flight are satisfactory.

Trimmability

16. The capability to trim the aircraft to a given airspeed and zero control force was evaluated concurrently with other testing. The trim system of the CSATB configured LONG-EZ was identical to the basic aircraft. A detailed description of the trim system is presented in USAAEFA Project No. 82-18, (ref 2, app A).

17. The inadequate longitudinal trimmability and the inaccessibility of the lateral trim system are previously reported shortcomings that remain uncorrected.

18. Directional trim characteristics were satisfactory throughout the flight envelope although there was no cockpit-adjustable rudder trim. Due to the lateral-directional stability characteristics (paras 21, 28 and 29), ball-centered flight was readily maintained in any configuration or condition tested with very light rudder pedal forces.

Static Longitudinal Stability

19. The static longitudinal stability characteristics of the LONG-EZ airplane were evaluated at the conditions shown in table 2. The aircraft was trimmed in level flight at the desired trim airspeed, then stabilized in 5 KIAS increments up to 20 KIAS faster or slower than the trim airspeed while maintaining constant throttle and trim settings. Longitudinal control positions were measured and control forces qualitatively evaluated with the test results presented in figures 12 through 14, appendix E.

20. The apparent stick-free static longitudinal stability, as indicated by the variation of control force with airspeed about trim, was weakly positive for all configurations tested. The control forces about the trim airspeed were relatively light (1 to 2 lb to vary airspeed ± 5 KIAS), but were not objectionable.

21. The stick-fixed static longitudinal stability, as indicated by the variation of longitudinal control position with airspeed, was weakly positive and in climb and landing configurations essentially identical. The weak stick-fixed stability was not objectionable due to positive stick-free stability. The static longitudinal stability characteristics met the requirements of

MIL-F-8785C. The static longitudinal stability of the CSATB configured LONG-EZ is satisfactory.

Static Lateral-Directional Stability

22. Static lateral-directional stability tests were performed at the conditions listed in table 2. The tests were conducted by trimming the aircraft (ball-centered), and then stabilizing in sideslips with zero turn rate at constant airspeed and engine speed (RPM). Test data are presented in figures 15 through 18, appendix E, and are essentially identical to data obtained near the aft cg limit for the basic aircraft. The sideslip indicator was a canopy-mounted yaw string. Apparent dihedral (variation of lateral control position with sideslip) and apparent directional stability (variation of directional control position with sideslip) were both positive. Directional stability was very strong as indicated by a rapid return to coordinated trim flight when the aircraft was released from sideslip. Pedal and lateral control forces were light, but provided adequate cues to out-of-trim conditions. There was no control force lightening observed. Sideforce cues (variation of bank angle with sideslip) provided an additional indication of out-of-trim conditions. The maximum sideslip angles in the landing configuration were 14 degrees left and 15 degrees right with full pedal displacement. This indicates a significant increase in the crosswind landing capabilities over the basic aircraft to a maximum crosswind landing component limitation of 25 knots from the previous limit of 15 knots. The yaw and roll control power in the power approach and landing configurations met the requirement of MIL-F-8785C. As a result, the previously reported shortcoming of limited directional control has been eliminated with the increase in rudder area.

Maneuvering Stability

23. Maneuvering stability characteristics were evaluated at the conditions presented in table 2. The variation of longitudinal control position and control force with normal acceleration was determined by trimming the aircraft in coordinated (ball-centered) level flight at 96 and 136 KCAS, and then stabilizing at incremental bank angles in steady turns, both left and right. Airspeed and power were held constant and the aircraft was allowed to descend during the maneuver. Data were obtained at each stabilized bank angle. Symmetrical pull-up and pushover maneuvers were conducted at a trim airspeed of 104 KCAS. Maneuvering stability data are presented in figures 19 and 20, appendix E, and are essentially identical to data obtained near the aft cg limit for the basic aircraft.

24. Maneuvering stability, as indicated by the variation of longitudinal control position (apparent stick-fixed stability) and control force (apparent stick-free stability) with normal acceleration, was positive (increased aft longitudinal control position and force with increased load factor) and essentially linear for all conditions tested. The longitudinal control position gradient varied from approximately 0.3 inches per g at 96 KCAS to 0.2 inches per g at 136 KCAS. Qualitatively, the longitudinal control force gradient was 5 to 7 pounds per g for all airspeeds tested. During maneuvering, normal accelerations to 3.5 g were easy to accomplish by banking the aircraft rapidly and applying a moderate amount (1/2 inch) of aft longitudinal stick. The stick-fixed and stick-free maneuvering stability is satisfactory.

25. The previously identified decrease in engine power during low g maneuvers is an uncorrected shortcoming that restricts maneuvering versatility. Additionally, on two occasions decreases in power were observed while maneuvering at 3.4 g at 104 KCAS. Release of aft stick resulted in immediate return to normal engine operation.

Dynamic Longitudinal Stability

26. The dynamic longitudinal stability characteristics were evaluated at the conditions shown in table 2. The long-term (phugoid) response characteristics were evaluated by varying the airspeed 10 and 20 KIAS above and below the trim airspeed, followed by returning the longitudinal control to the trim position (stick-fixed) or releasing the control and allowing it to seek the trim position (stick-free). Short-term dynamic characteristics, simulating gust response, were evaluated by introducing longitudinal control pulses (1 in. from trim for a duration of 0.5 sec). Representative times histories are presented in figures 21 and 22, appendix E. Test results are summarized in table 4.

27. The long-term (phugoid) response of the LONG-EZ was oscillatory, moderately damped, and not easily excited in the cruise configuration at 116 KIAS. The period was approximately 40 seconds. From trim, the phugoid caused airspeed variations of less than 3 knots, but did not degrade aircraft control. The long-term dynamic characteristics of the LONG-EZ met the requirements of MIL-F-8785C and are satisfactory.

28. Longitudinal short-term characteristics were essentially deadbeat for all test conditions, including flight in light and moderate turbulence. The short-term characteristics met the

Table 4. Dynamic Longitudinal Characteristics

Dynamic ¹ Characteristics	Trim Indicated Airspeed (kt)	Period (sec)	Natural Frequency (rad/sec)	Undamped Natural Frequency (rad/sec)	Damping Ratio
Long-term	103	40	0.1686	0.1571	0.3630
Short-term	103	1.4	4.860	4.488	0.3837

NOTES:

¹Propeller speed: 2525 RPM, Gross weight: 1330 lb, CG: FS 101.1 (mid),
cruise configuration.

requirements of MIL-F-8785C. For the conditions investigated, the short-term longitudinal dynamic characteristics are satisfactory.

Dynamic Lateral-Directional Stability

Dutch Roll Characteristics:

29. The dynamic lateral-directional stability characteristics (lateral-directional damping and dutch roll characteristics) were evaluated at the conditions shown in table 2. These tests were conducted by exciting the aircraft from a coordinated level flight trim condition with either aileron pulses or doublets, rudder doublets, or release from sideslips. Time histories of representative dynamic lateral-directional responses are presented in figures 23 through 26, appendix E. The lateral-directional oscillations were heavily damped and not easily excited. The dutch roll period was approximately three seconds with a damping ratio of approximately 0.7 and roll-to-yaw ratios of approximately 1:1.5. In light to moderate turbulence without pilot inputs the dutch roll tended to damp out in two or three cycles. The dutch roll characteristics of the CSATB configured LONG-EZ are satisfactory.

Spiral Stability:

30. The spiral stability characteristics of the LONG-EZ aircraft were evaluated at the conditions shown in table 2. These tests were conducted by establishing 10 and 20 degree bank angles (both left and right) from trim conditions, using aileron or rudder only, and then after stabilizing at the prescribed bank angle, the control was slowly returned to trim. Spiral stability, as indicated by change in bank angle with elapsed time was convergent (approximately 3 to 4 seconds time to half amplitude) for both left and right turns. Any small disturbance of the lateral or directional control system or gust would result in a tendency for the aircraft to return to trim without pilot compensation. The spiral stability of the CSATB configured LONG-EZ is satisfactory.

Gust Response:

31. Roll oscillations in light to moderate turbulence (fig. 27, app E) with the FLIR sensor installed were similar to those previously reported with extension of the landing air brake. The pilot workload in turbulence required to maintain runway alignment and glide path control is essentially unchanged and remains

objectionable during the landing task. The roll oscillations in light to moderate turbulence remains a shortcoming.

Roll Control Effectiveness

32. Roll control effectiveness was evaluated at the conditions shown in table 2. These tests were initiated from trimmed unaccelerated flight conditions by applying 1/4 to full-lateral control inputs (in 0.2 sec) in approximately 1/4-inch increments without changing longitudinal or directional pedal control position. Representative time histories of airplane response with 1 inch and full deflection lateral control inputs are presented in figures 28 through 31, appendix E, and summarized for all deflections in table 5. Time required to roll 60 degrees left and right for full control deflections was 1.5 sec and 2.3 sec, respectively. Roll rates to the right appeared to be more heavily damped than to the left achieving much lower steady state roll rates. Although noticeable during the evaluation, the difference in roll rates was not objectionable while maneuvering in flight. A higher roll rate was perceived initially with the steady state rate being reached in approximately 1 second. Control forces were qualitatively determined to be light (less than 5 lb maximum) and proportional to control displacement. Roll-to-pitch and roll-to-yaw cross coupling was not noticeable and there were no adverse handling qualities. There was, however, a perceptible, but not objectionable, adverse yaw associated with the lateral control inputs. The roll control effectiveness met the Class I, Category B (light-reconnaissance airplane) requirements of MIL-F-8785C. The roll performance characteristics of the LONG-EZ are satisfactory.

Takeoff and Landing Characteristics

General:

33. Takeoff and landing characteristics were evaluated in conjunction with takeoff and landing performance testing (paras 8 and 15, respectively) and qualitatively during all other testing. A representative time history of each task is presented in figures 32 and 33, appendix E.

Takeoff:

34. During the initial portion of the takeoff roll (below 30 KIAS) in calm to variable light wind conditions (less than 7 knots) continuous to intermittent braking was required to maintain runway heading (HORS 4). With gusty crosswind conditions (up to 45 degrees off the nose) at 10 to 25 knots further intermittent

Table 5. Roll Control Effectiveness¹

Control Deflection (in.)	Roll Mode Time Constant (T _R -sec)	Steady State Roll Rate (deg/sec)
Left		
0.4	.13	10
0.6	.13	17
1.2	.13	20
1.8	.12	35
Right		
0.9	.10	17
1.3	.10	20
1.8	.09	22

NOTE:

¹Trim airspeed 100 KCAS

braking was necessary up to 50 KIAS to maintain heading (HQRS 5). The minimum rotation airspeed was 56 KIAS with minimum liftoff airspeed at 65 KIAS. Control power was not available to affect an earlier rotation or liftoff at the conditions tested. Pitch attitudes were approximately 12 degrees during takeoff and were not uncomfortable to the pilot. Climbout airspeeds were easy to maintain except during gusty conditions where large uncommanded changes in roll and pitch were experienced (HQRS 6) (para 32).

Landing:

35. Landing approaches under calm to gusty crosswind conditions (10-20 knots) were accomplished at a constant airspeed with power at idle except for occasional small power applications to adjust the touchdown point. Approaches made at 75 KIAS resulted in excessive float prior to touchdown (several hundred feet). Approaches made at 70 KIAS were accompanied by very little float and the glide path to touchdown could be adequately controlled with power (HQRS 3). Approaches performed at 65 KIAS required continuous power modulation to maintain glide path control (HQRS 5) with approximately 2-3 degree higher pitch attitudes than experienced during approaches at 70 KIAS. These higher pitch attitudes further degraded the forward field-of-view by obscuring the intended touchdown point. During gusty conditions the roll oscillations (para 32) significantly increased pilot workload necessary to maintain wings level flight during the approach (HQRS 5). Sufficient control power and authority was available during all conditions tested to affect a smooth touchdown while maintaining runway heading. Directional control requirements during the landing roll were similar to those required for takeoff below 50 KIAS. Under turbulent crosswind conditions with wind gusts to 22 knots, however, the directional control limits were reached several times during the landing flare in order to maintain runway heading (HQRS 6).

36. Based upon the demonstrated takeoff and landing characteristics and increase in sideslip capability (para 21) the maximum recommended takeoff and landing crosswind component limitation should be changed from 15 to 20 knots (ref 5, app A) for the CSATB configured LONG-EZ aircraft. A previously reported deficiency (ref 2, app A) pertaining to the loss of directional control due to single point brake failure during takeoff/landing and ground handling remains uncorrected, although improved.

Stall Characteristics

37. Stall characteristics were evaluated in conjunction with stall performance testing (para 12). During unaccelerated stalls control forces were light during the approach to the stall with very little lateral or directional control required to keep the aircraft straight and level. There was essentially no stall warning. The canard stall was defined by a docile pitch break, or pitch oscillation, at full aft longitudinal control. Deep stall reactions were characterized by a gentle nose drop, and the aircraft entered a mild longitudinal oscillation with about a 10 second period and airspeed variations of 6 to 8 KIAS. The test aircraft exhibited a slight (2-3 degree) increase in pitch break over the clean configuration tested in USAAEFA Projects No. 82-18 and 83-18 (refs 2 and 3, app. A). With the longitudinal control full aft there was no tendency for the aircraft to depart controlled flight. There were almost no lateral or directional control input requirements to maintain a desired flight path. Recovery was accomplished by release of aft longitudinal control pressure and addition of power (except for climb configuration). The aircraft immediately returned to level flight. The mild stall characteristics, ease of recovery, and mild post-stall reactions give the pilot increased confidence in his ability to operate the aircraft in the low airspeed regime. The lg stall characteristics of the CSATR configured LONG-EZ aircraft are satisfactory. The CSATR configured LONG-EZ stall characteristics failed to meet the requirements of paragraph 3.4.2.1.1 of MIL-F-8785C, in that there was no easily perceptible warning of approaching stall. The absence of the stall warning remains a shortcoming.

38. Accelerated stalls were conducted using constant bank angle turns and applying aft longitudinal control to establish a 2 knots per second deceleration until stall occurred. There was no stall warning. The approach to stalls and post-stall reactions were mild and required almost no lateral or directional inputs to maintain roll attitude. Longitudinal control forces were considerably higher than the lg stalls. The longitudinal control had to be pulled against the aft stop to effect a stall. The pitch break was mild and the post-stall reactions were similar to the lg stall characteristics. The mild stall characteristics and good aircraft controllability during the stall increases the pilot's confidence to maneuver. The accelerated stall characteristics failed to meet the requirements of paragraph 3.4.2.1.1 of MIL-F-8785C, in that there was no warning of approaching a stall. The accelerated stall characteristics of the CSATR configured LONG-EZ are satisfactory.

VIBRATION CHARACTERISTICS

39. The forward flight vibration characteristics of the LONG-EZ with the FLIR sensor installed were qualitatively evaluated throughout the test program and quantitatively evaluated at the conditions listed in table 2. Three axis vibration data intended to supplement the data obtained during the initial PAE (ref 2, app A) were measured at the upper, aft, center section of the FLIR flange mount (photo 5, app C) and are presented in figures 34 through 42, appendix E. Quantitatively, vibration analysis of the FLIR mount data indicates five distinctive aircraft responses; a wing torsional resonant excitation of 15 hertz (HZ), an asymmetric winglet resonant excitation of 22.9 HZ, and the first, second, and fourth harmonic of the propeller speed. These vibrations were greatest in the 95 to 105 KCAS range at propeller speeds greater than 2400 RPM. At the 4 per revolution harmonic the vibratory accelerations were between 0.6 and 0.9 g in all axes. At the same conditions, a 2/rev vibratory acceleration in the FLIR vertical axis was measured in excess of 0.8g. Qualitatively, the objectionable engine/propeller vibration characteristics experienced between 90 to 100 KCAS at power required for level flight or greater (engine RPM 1900-2800) are essentially unchanged. As previously reported, the engine/propeller vibration characteristic between 90 to 100 KCAS at power required for level flight or greater remains a shortcoming.

NIGHT EVALUATION

40. A qualitative night evaluation was conducted to determine the suitability of the cockpit lighting, instrument displays, and landing light during night operations. Night visibility and internal and external light reflectivity characteristics on the canopy were evaluated on the ground by covering the canopy to simulate "black night" conditions and during actual night flight over both sparsely lighted and mid to high density lighted (city and airport) areas between 500 to 3000 feet above the ground. Takeoff, approach and landing tasks were performed to a fully lighted US Air Force standard Level 1 (minimum), Level 3 (medium) and Level 5 (maximum) runway environment, with and without use of the landing light. Adequate cockpit and instrument lighting was attainable through use of the instrument panel lights rheostat control and integral lighting features of primary flight instruments and avionics equipment with no apparent degradation in the night field-of-view. Additionally, piloting tasks such as reading of kneeboard data or map navigation was easily accomplished through use of the instrument panel lights set to approximately 70 percent of maximum intensity without objectionable internal

light reflections on the canopy. Objectionable internal light reflections on the canopy (approximately 10 percent of the center forward field-of-view) occurred whenever the landing light was illuminated. To minimize this effect the pilot positioned his left leg over the landing light control lever panel to partially shield the landing light glare. Use of the landing light was essential to prevent high round-out (approximately 10 to 15 ft above the ground) during the landing flare for all levels of runway lighting tested. The objectionable internal light reflections of the landing light on the canopy is a shortcoming.

ELECTRO-MAGNETIC COMPATABILITY

41. Qualitative evaluation of installed electrical and avionics equipment electro-magnetic compatibility was conducted throughout the test program. During the ground night cockpit lighting evaluation, it was observed that the King Instruments, Inc., KLS-55A compass system, precessed at a constant rate when the instrument light rheostat was adjusted to greater than 50 percent intensity even through the circuit breaker controlling the compass system was deactivated. When power was applied to the compass system the precession ceased once the system was aligned with the heading flux valve. Subsequent variation of the instrument light rheostat had no apparent effect on the compass system and was not objectionable to the pilot. As previously reported, the false increase in propeller speed indications caused by the very high frequency transmitter remains a shortcoming.

MISCELLANEOUS

Weight and Balance Determination

42. Prior to flight testing, a weight and balance determination was conducted on the aircraft in the instrumented configuration, both with and without crew. A post-evaluation weighing was conducted to verify gross weight and cg location after test instrumentation was removed. The aircraft basic weight and cg were 995 lb at FS 110.58 uninstrumented, and 1093.2 lb at FS 109.1 instrumented.

Pitot-Static System Calibration

43. The pitot-static position error of the standard ship's system was determined at conditions presented in table 2 using the calibrated pacc method. The test results are presented in figure 43, appendix E. The maximum position error was +6 knots.

at 80 KIAS and gradually decreased to a 1 knot error within the airspeed range of 120 to 150 KIAS. The position error characteristics of the ship's airspeed system are unchanged by the FLIR installation.

Engine Cooling Characteristics

44. Engine cooling characteristics were evaluated throughout the tests and at the conditions listed in table 2 during maximum continuous power climbs from 86 to 106 KCAS. During the tests the outside air temperature varied from 22 to 78 degrees fahrenheit. Cylinder head temperatures were consistent with previously reported data and within recommended operating limits. The number four cylinder continues to indicate the highest temperature.

CONCLUSIONS

GENERAL

45. The following conclusions were reached upon the completion of the PAE evaluation of the CSATB configured LONG-EZ aircraft.

a. The performance capabilities and handling qualities are adequate for the CSATB evaluation including night operations (para 6).

b. Modification of the basic airframe to the CSATB configuration (with the FLIR sensor installed) resulted in an equivalent flat plate area (F_e) increase of 2.09 square feet in the cruise configuration and 0.76 square feet for the landing configuration (para 10).

c. Handling qualities at the mid cg were essentially identical to those obtained near the aft cg limit, FS 104.0, for the basic aircraft, and therefore, the aft cg should be limited to FS 101.5 for the CSATB configured aircraft (para 14).

d. There were no new deficiencies and one additional shortcoming identified during this evaluation (para 6).

e. One previously reported shortcoming of limited directional control has been eliminated (para 22).

DEFICIENCY

46. The following deficiency was identified during the initial PAE evaluation of the LONG-EZ aircraft and has not been corrected: The loss of directional control due to single point brake failure during takeoff/landing and ground handling (para 36).

SHORTCOMINGS

47. The following new shortcoming was identified: The objectionable internal light reflections of the landing light on the canopy (para 40).

SPECIFICATION COMPLIANCE

48. The LONG-EZ aircraft met all the requirements of the specification, MIL-F-8785C against which it was tested except for paragraph 3.4.2.1.1 in that there was no easily perceptible warning of approaching stall (para 37 and 38).

RECOMMENDATIONS

49. The uncorrected deficiency identified during this evaluation should be corrected as a matter of highest priority if development continues (para 6).

50. The shortcoming should be corrected prior to production (para 6).

51. Incorporate the following NOTE from para 9 of this report in the operator's manual:

NOTE

An abrupt decrease in both indicated airspeed (typically 3 to 6 knots) and pressure altitude (approximately 50 feet) will occur coincident with rotation due to an apparent static port position error change.

APPENDIX A. REFERENCES

1. Federal Air Regulation, Federal Aviation Administration, FAR Part 21, *Certification Procedures for Products and Parts*, 1 January 1981.
2. Final Report, USAAEFA Project No. 82-18, *Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory (RAF), Inc. LONG-EZ Airplane*, June 1983.
3. Letter Report, USAAEFA No. 83-18, Preliminary Airworthiness Evaluation of the Rutan Aircraft Factory Inc. LONG-EZ Airplane (S/N 1241), 15 December 1983.
4. Letter, AVSCOM, DRSAB-E, 9 March 1984, subject: Test Request No. 84-04, Preliminary Airworthiness Evaluation of Rutan Aircraft Factory, Inc. LONG-EZ with External Sight.
5. Owner's Manual, *Rutan Aircraft Factory, Inc. LONG-EZ Aircraft*, Second edition, October 1981,
6. Letter, AVSCOM, DRSAB-E, 14 March 1984, with revision 1, 23 March 1984, subject: Airworthiness Release for Rutan Aircraft Factory (RAF), Inc. LONG-EZ Aircraft S/N 1241.
7. Flight Test Manual, Naval Air Test Center, FTM No. 104, *Fixed Wing Performance*, July 1977.
8. Flight Test Manual, Naval Air Test Center, FTM No. 103, *Fixed Wing Stability and Control*, 1 January 1975, revised 1 August 1972.
9. Military Specification, MIL-F-8785C, *Flying Qualities of Piloted Airplanes*, 5 November 1980.
10. Federal Air Regulation, Federal Aviation Administration, FAR Part 91, *General Operating and Flight Rules*, 1 January 1981.
11. Sighard, F. Hoerner, *Fluid Dynamic Drag*, 1965

APPENDIX B. DESCRIPTION

GENERAL

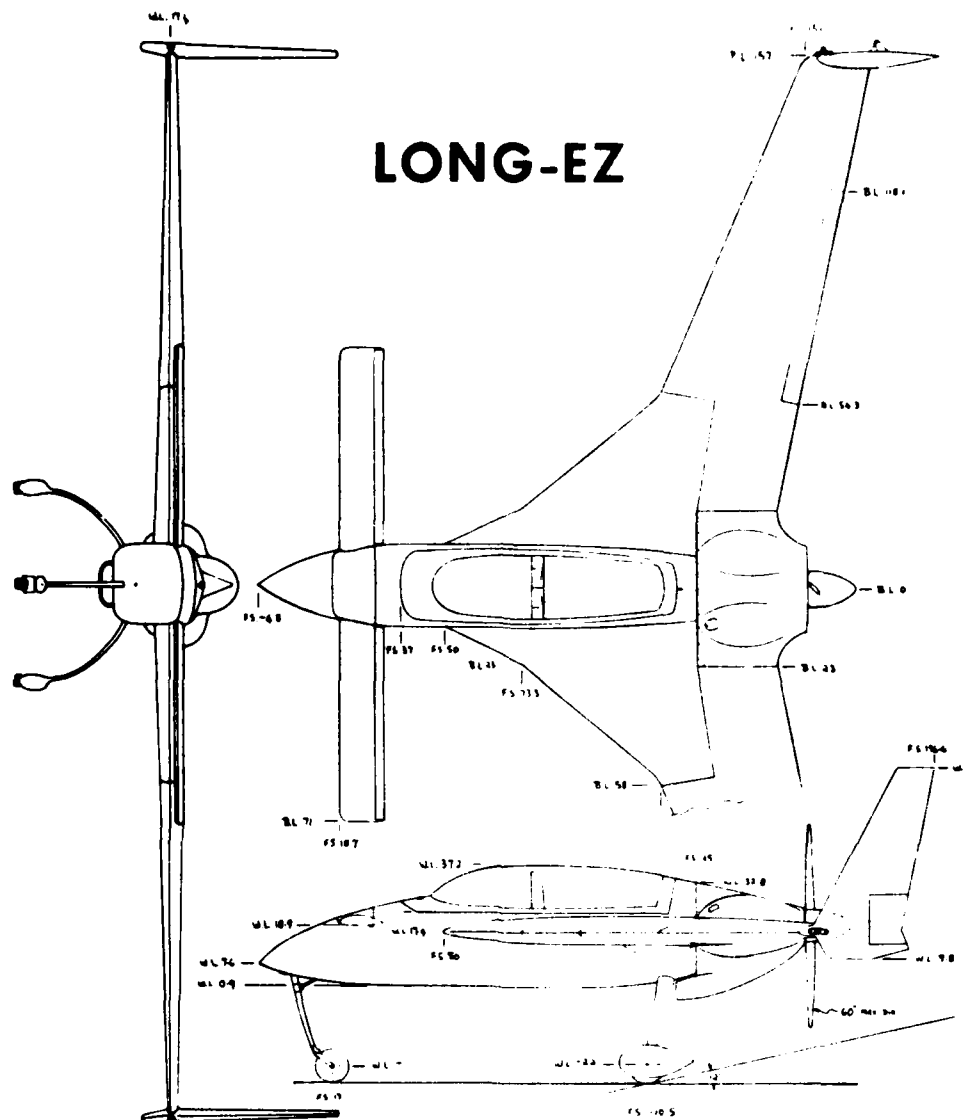
1. The LONG-EZ airplane is a small, lightweight, home-built experimental class aircraft designed by Rutan Aircraft Factory (RAF), Inc. and privately constructed according to the LONG-EZ manufacturing plans. It is certified under FAR Part 21 (ref 1, app A) and operated in accordance with the provisions of FAR Part 91.42 (ref 10, app A). A complete description of the unmodified aircraft is contained in the owner's manual (ref 5, app A) and a three-view drawing of the aircraft with dimensions and general data is presented in figure 1.

COMBAT SURVEILLANCE AIRBORNE TEST BED (CSATB)

2. The basic LONG-EZ airplane has been modified to the CSATB configuration by the addition of a mission equipment package consisting of an external, belly mounted, forward looking infrared (FLIR) sensor, a loran receiver, a King KLS-55A compass system, and an encoding altimeter. A schematic drawing of the mission configured aircraft is presented in figure 2. Photos 1 through 4 show the test CSATB configured aircraft. The loran receiver and the compass system indicator are mounted on the front instrument panel (photo 5). A side panel has been added to accommodate front panel instruments relocated by these two systems (photo 6). Additionally, the original rudder system (1.07 sq ft), has been replaced by larger high aspect ratio rudders (1.85 sq ft), located on the winglets at the wing tips. Because of the location of the infrared sensor (directly in front of the original engine air inlet the engine cowling was redesigned for improved cooling. Two air inlets, each 60% of the size of the original, were mounted on the side of the engine underneath the wing. A landing light has been installed to accommodate night VFR operation. It is manually deployed and mounted on the belly of the aircraft in front of the air brake. Principal dimensions and airfoil geometry of the CSATB configured LONG-EZ are identical to those of the unmodified aircraft and can be found in reference 2, appendix A.

FORWARD LOOKING INFRARED (FLIR) SYSTEM

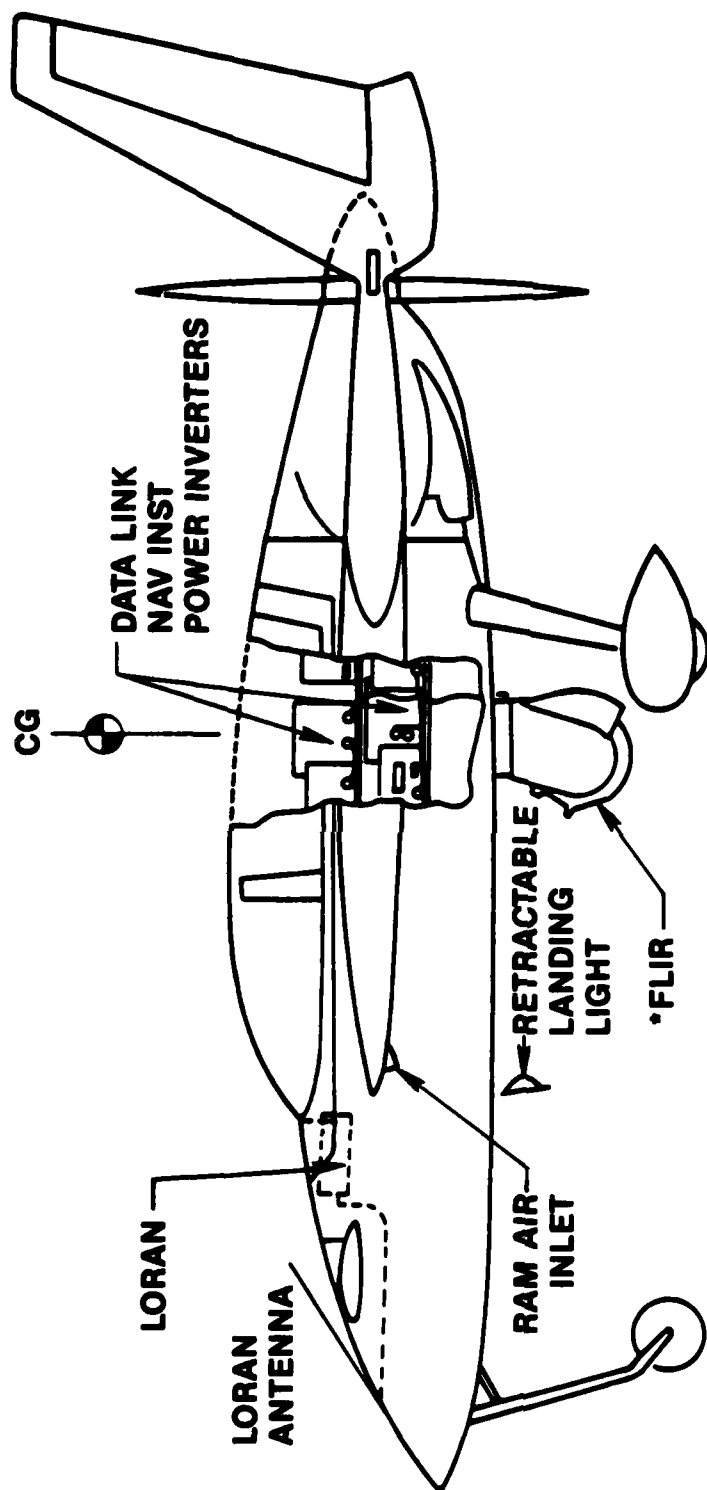
3. A series 2000 FLIR system, manufactured by FLIR Systems, Inc. of Lake Oswego, Oregon, is belly mounted at FS 100. Figure 3 depicts dimensions and weight of the external sensor component. The FLIR is supported by framing mounted in the rear cockpit seat which eliminates the rear seating capability of the CSATB configured LONG-EZ.



DIMENSIONS AND GENERAL DATA

WING SPAN	26.1 FT	ENGINE LYCOMING	O-235 L2C
WING AREA	94.8 SQ FT	RECOMMENDED FUEL	100LL OR 100/130
CABIN		MAX FUEL CAPACITY	52 GALLONS
LENGTH	100 IN	MAX GROSS WEIGHT	1325 LBS
WIDTH	23 IN		
HEIGHT	37 IN		

Figure 1. Dimensions and General Data



*POSSIBILITY OF CCD VIDEO CAMERA MOUNTED IN FLIR OR VIDEO CAMERA(S) ON INTERCHANGEABLE TWO-AXIS GIMBAL ASSEMBLY

Figure 2. Mission Configured LONG-EZ

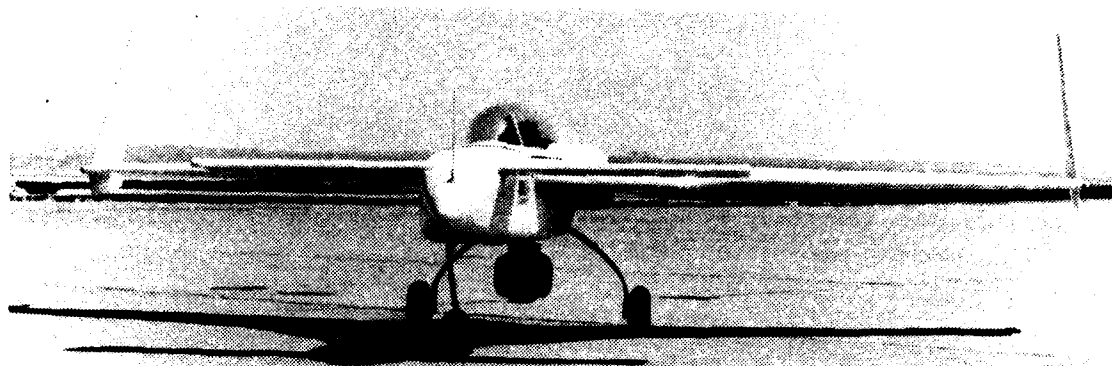


Photo 1. Left Quartering Front View

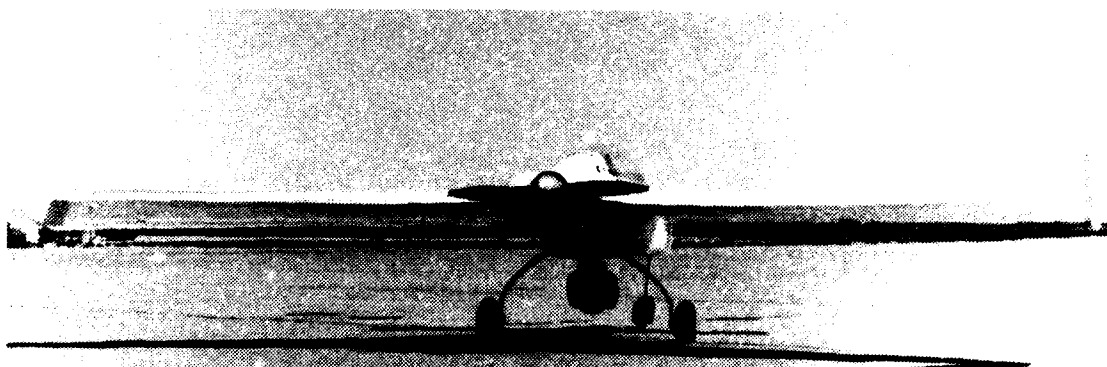


Photo 2. Right Quartering Rear View

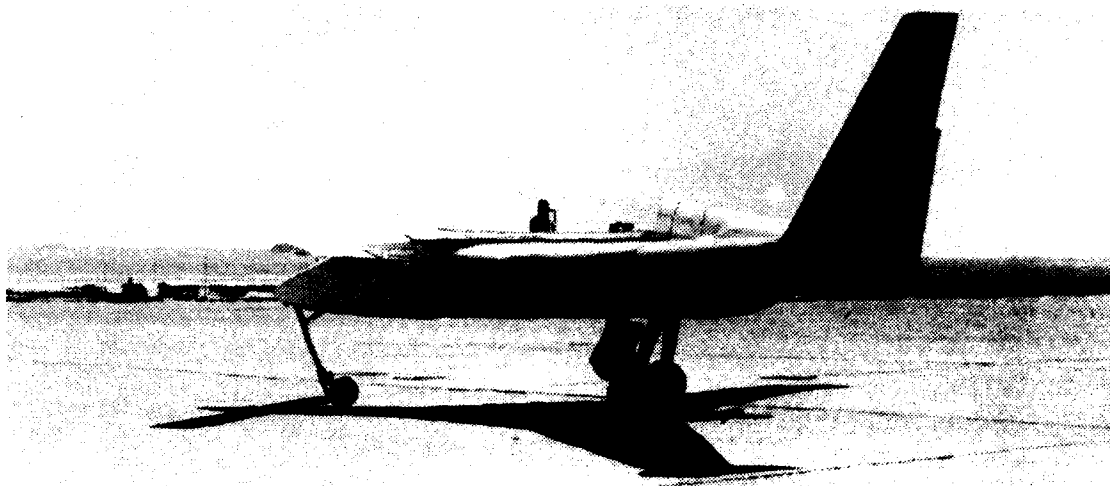


Photo 3. Left Side View

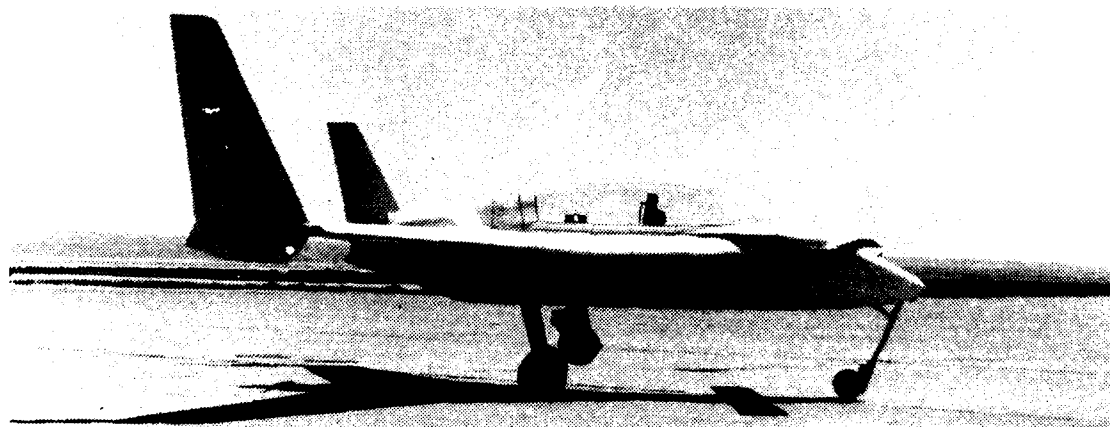


Photo 4. Right Side View



Photo 5. Front Instrument Panel

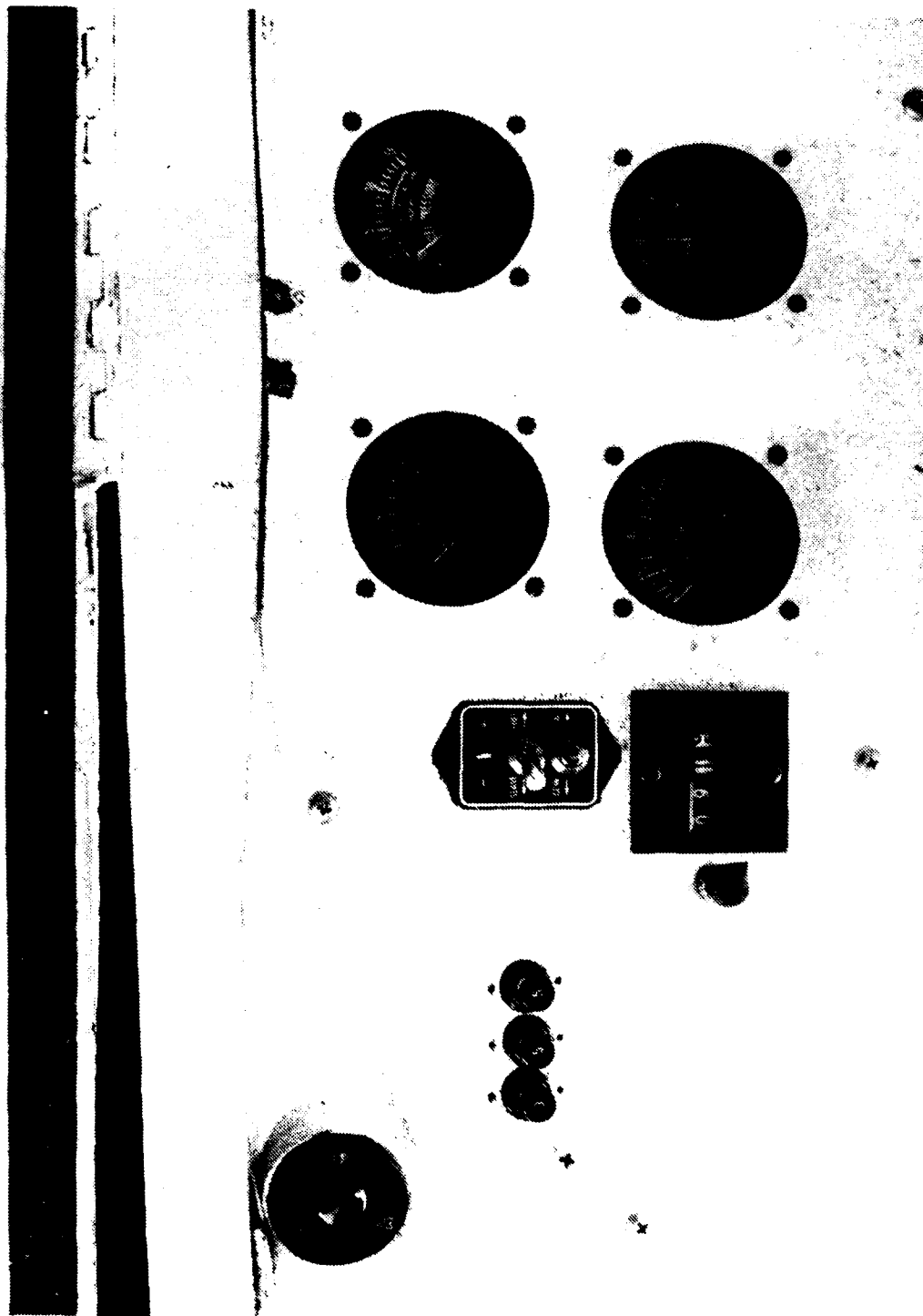


Photo 6. Right Side Instrument Panel

FLIGHT CONTROLS

4. The LONG-EZ is equipped with a reversible type mechanical flight control system actuated through the side-arm control stick (pitch and roll) and rudder pedals (yaw). Flight controls are provided only in the front cockpit of the CSATB configured LONG-EZ. The control stick normally located in the rear seat has been removed in the CSATB configured aircraft. The cockpit flight controls are identical to those described in reference 2, appendix A. Control system rigging is presented in table 3.

Table 3. Control System Rigging

Control	Average Measured	Tolerance
ELEVATOR		
<u>Left</u>		
Travel		
Trailing edge up	22.0°	20°+2° TEU
Trailing edge down	20.7°	22°+ 2° TED
Free play (static)	0.04 in.	-----
<u>Right</u>		
Travel		
Trailing edge up	21.1°	20°+2° TEU
Trailing edge down	20.4°	22+2° TED
Free play (static)	0.04 in.	-----
Total longitudinal control travel	2.5 in.	
AILERONS		
<u>Left</u>		
Travel		
Trailing edge up	2.0 in.	2.1 in.+0.3in. TED
Trailing edge down	1.92 in.	2.1 in.+0.3in. TED
Free play (static)	0.1 in.	-----
<u>Right</u>		
Travel		
Trailing edge up	2.05 in.	2.1 in.+0.3in. TEU
Trailing edge down	2.1 in.	2.1 in.+0.3in. TED
Free play (static)	0.02 in. TED	
Total lateral control travel	3.7 in.	
RUDDERS		
Left deflection	5.9 in.	6 in.+0.5 in.
Total left directional control travel	1.4 in.	
Right deflection	5.75 in.	6 in.+0.5 in.
Total right directional control travel	1.17 in.	

APPENDIX C. INSTRUMENTATION

1. An airborne data telemetry system was installed and maintained by USAAFEFA. The system utilized pulse code modulation (PCM) encoding and incorporated a self-contained 24 VDC power source with sufficient capacity for a minimum of one hour test duration. The data was transmitted to the Real Time Data Acquisition and Processing (RDAPS) for processing and storage.

2. Instrumentation and related special equipment installed are presented below. Photos 1 through 6 show the cockpit instrument panel, auxillary instrument panel controls, cockpit location and installation of the airborne data telemetry system, and the FLIR system vibration sensor location.

Pilot Station (Front cockpit display)

- Sensitive airspeed
- Sensitive normal acceleration
- Calibrated altimeter
- Calibrated engine speed
- Cylinder head temperatures (4)
- Exhaust gas temperatures (4)

Airborne Data Telemetry System

- Pilot event
- Airspeed
- Altitude
- Pitch attitude
- Roll attitude
- Pitch rate
- Roll rate
- Yaw rate
- Normal acceleration (CG)
- Longitudinal control position
- Lateral control position
- Rudder pedal position left
- Rudder pedal position right
- Fuel flow
- Fuel totalizer
- Outside air temperature
- IR sensor vertical vibration
- IR sensor lateral vibration
- IR sensor longitudinal vibration

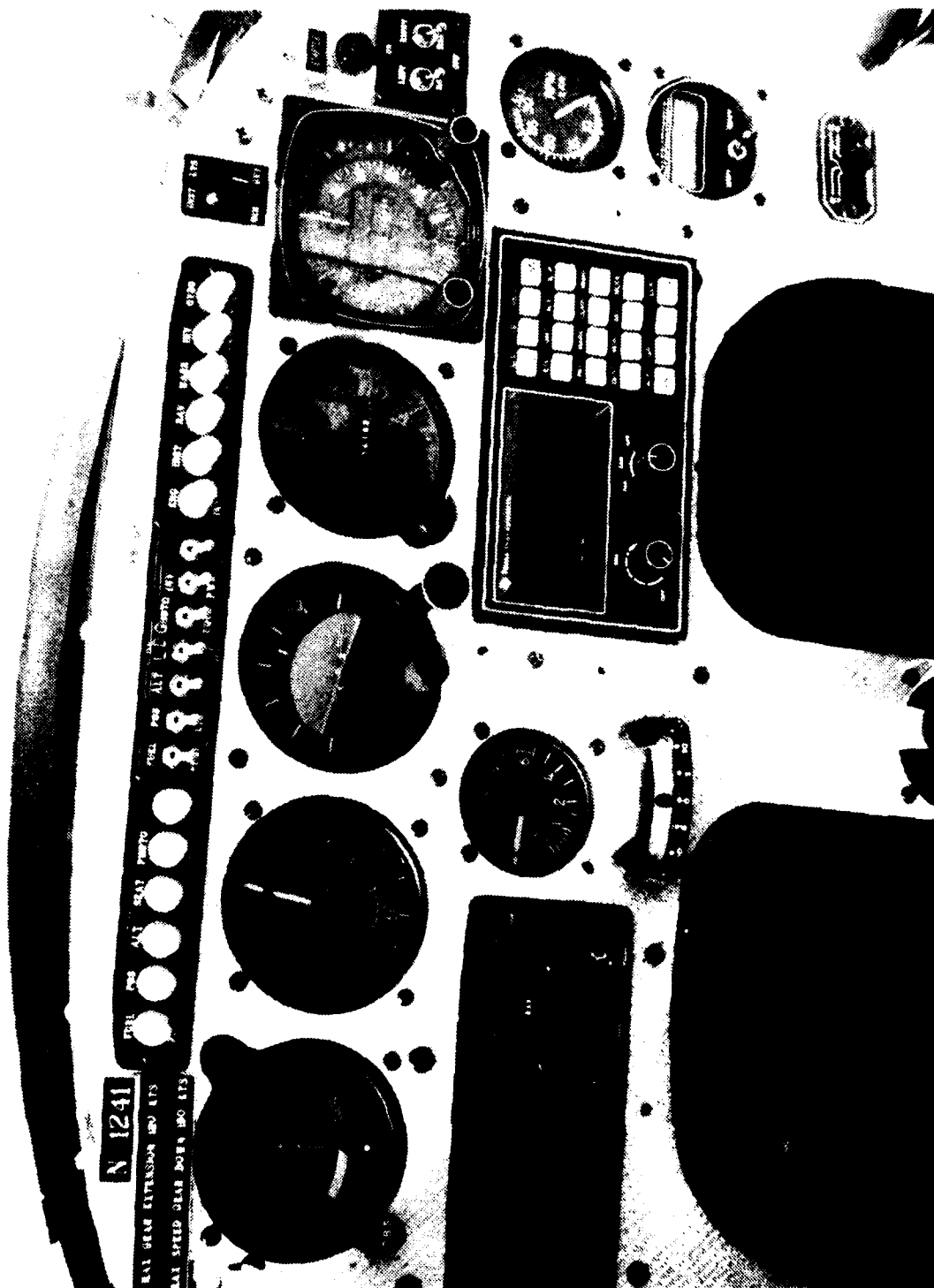


Photo 1. Cockpit Instrument Panel

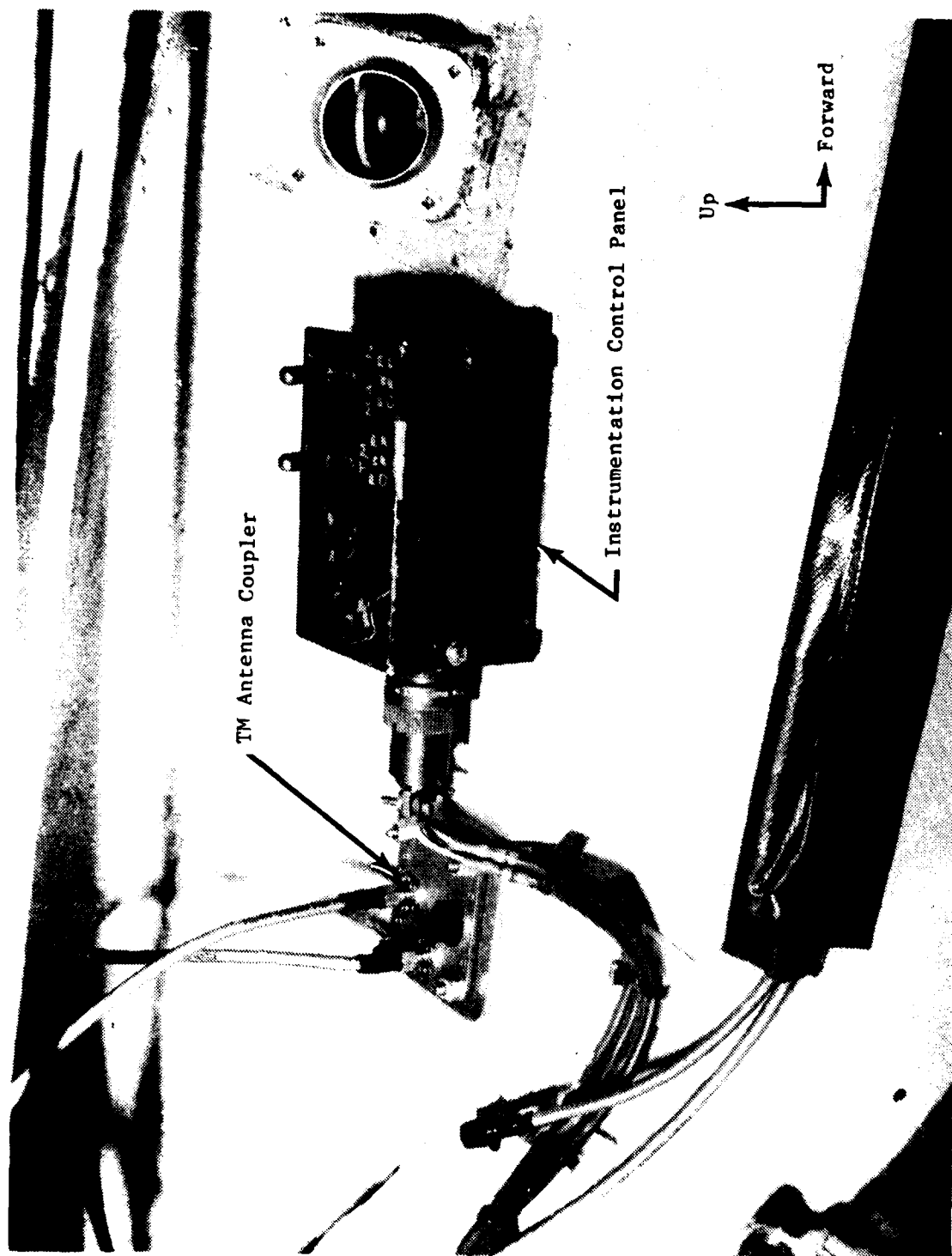


Photo 2. Auxillary Instrument Panel Controls
(Front Cockpit)



Photo 3. Instrumentation Aft Cockpit

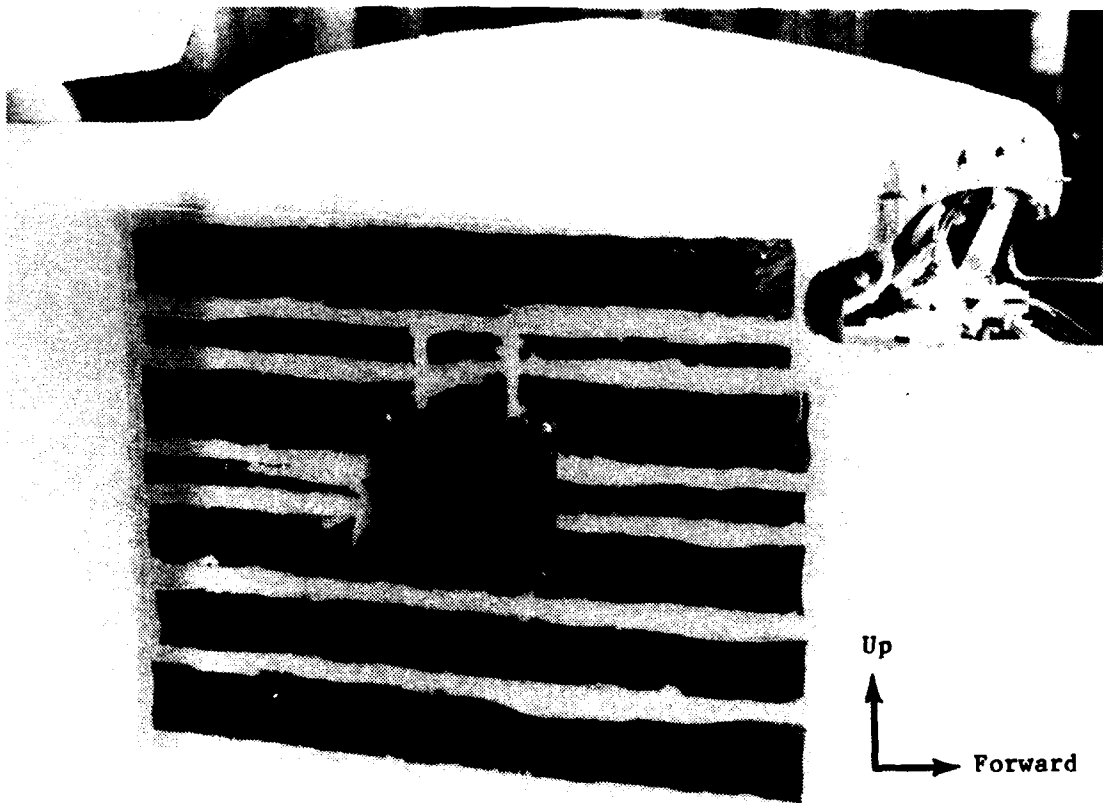


Photo 4. Right Side Telemetry Antenna

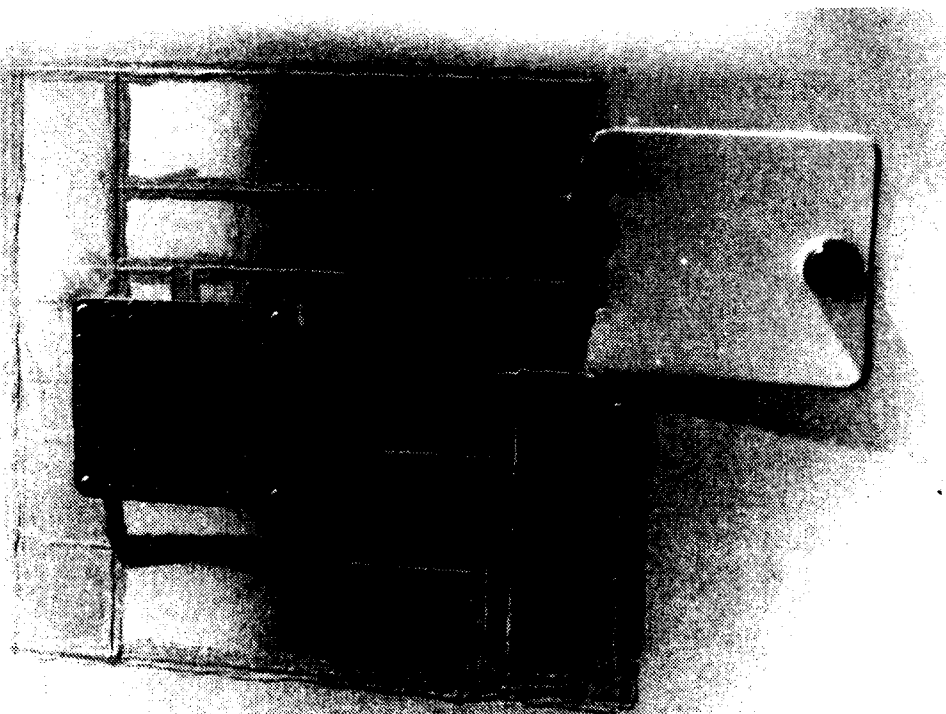


Photo 5. Left Front Fuselage - TM Antenna



Photo 6. FLIR Flange Mount Accelerometer Location

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. This appendix contains some of the data reduction techniques and analysis methods used to evaluate the LONG-EZ aircraft. Topics discussed include glide, level flight, takeoff and landing performance, airspeed calibration, and weight and balance.

GLIDE PERFORMANCE

2. The propeller stopped glide method was used to define the drag of the LONG-EZ aircraft in the cruise and landing configurations. The method involved obtaining flight data while the aircraft was stabilized in a constant-airspeed descent with the engine shutdown and propeller stopped. Parameters measured included airspeed, pressure altitude, outside air temperature, gross weight, and elapsed time. The airspeed range from 1.1V_S to maximum operating airspeed with the propeller stopped was investigated through a target pressure altitude (Hp) band of 10,000 to 6,000 feet. The technique used to develop the baseline-drag equation is shown below.

$$L = W \cos \theta$$

$$D = T + W \sin \theta$$

$$DV_T = TV_t + WV_t \sin \theta$$

$$-V_T \sin \theta = \frac{dh}{dt} = \frac{TV_t - DV_t}{W}$$

Where:

L = Lift force (lb)

W = Aircraft gross weight (lb)

θ = Descent angle (deg) = $\sin^{-1} \frac{dhp/dt}{V_T}$

T = Net thrust (lb) = zero with propeller stopped.

D = Drag force (lb)

V_t = Aircraft true airspeed on flight path (ft/sec)

$$\frac{dh}{dt} = \text{Tapeline rate of descent (ft/sec)} \frac{dH_p}{dt} \frac{T_{a_t}}{T_{a_s}}$$

$$\frac{dH_p}{dt} \text{ is measured}$$

where:

T_{a_t} = test day ambient temperature ($^{\circ}\text{K}$)

T_{a_s} = standard day ambient temperature ($^{\circ}\text{K}$)

Considering the drag and lift force equations and applying power-off glide conditions, the following non-dimensional relationships can be developed:

$$C_D = \frac{D}{qs}$$

$$C_D = \frac{W \sin \theta}{qs}$$

$$C_L = \frac{L}{qs}$$

$$C_L = \frac{W \cos \theta}{qs}$$

Where:

C_D = Coefficient of drag

$q = 1/2 \rho V_T^2$ (lb/ft²) dynamic pressure

S = Total wing area (ft²)

C_L = Coefficient of lift

ρ = Air density (slug/ft³)

The drag equation (C_D) was then developed by plotting C_D versus C_L² and fitting a first-order equation to the test points.

$$C_D = C_{D0} + \frac{\Delta C_D}{\Delta C_L^2} C_L^2$$

Coefficient of drag of the stopped propeller was determined from methods described in Hoerner's Fluid-Dynamic Drag (ref 11, app A) and the following equation.

$$C_{D_{prop}} = 0.1 + \cos^2 R$$

Where:

C_{D_{prop}} = Coefficient of drag of the propeller blade

R = blade angle at 0.7 radius

The drag of the stopped propeller is then calculated from the following equation.

$$\text{Drag}_{prop} = C_{D_{prop}} \times q \times S_{blade}$$

Where:

Drag_{prop} = Drag of the stopped propeller

S_{blade} = The developed blade area which includes blockage effects of the fuselage estimated to be 0.9 ft² for the Ted's propeller)

TAKEOFF AND LANDING PERFORMANCE

3. Takeoff and landing performance was evaluated at a constant density altitude of 2700 feet using ground observers and a visual theodolite to quantify distance.

4. Takeoff data were corrected to standard conditions. The wind correction was the first to be applied. For winds less than 5 knots, the equation is:

$$Sg_w = Sg \left(1 + \frac{V_w}{V_{To}} \right) 1.85$$

Where:

Sg = Ground distance (ft)

V_w = Wind velocity (ft/sec)

V_{To} = Velocity at takeoff (ft/sec)

Sg_w = Ground distance corrected for wind (ft)

Corrections for runway slope were made with the following equation:

$$Sg_{SL} = \frac{Sg_w}{1 + \frac{\frac{2g Sg_w}{V_{To}^2} \sin \theta}}$$

Where:

Sg_{SL} = Ground distance corrected for slope (ft)

θ = Runway slope (positive uphill in degrees)

g = Acceleration due to gravity - 32.1741 ft/sec²

The combined equations for thrust, weight, and density corrections are shown below. The subscripts, t and s, refer to test data (corrected for wind and runway slope) and standard data, respectively.

$$\frac{Sg_s}{Sg_t} = \left[\frac{\frac{W_s}{W_t} \frac{\sigma_t}{\sigma_s}}{\frac{2g Sg_t}{W_t V_{To_t}^2} \left(\frac{W_t}{W_s} F_{n_s} - F_{n_t} \right)} + 1 \right]$$

Where:

Subscript s refers to standard data

Subscript t refers to test data

Sg = Ground distance (ft)

w = Gross weight (lb)

σ = Air density ratio

g = Acceleration due to gravity (ft/sec²)

V_{TO} = Velocity at takeoff (ft/sec)

F_n = Mean net thrust

5. Dynamic stability characteristics were evaluated to determine the damping ratios and damped natural frequencies. They were derived for all conditions tested by the transient peak ratio.

6. The two transient peak ratio methods used for lightly damped, moderately damped, and unstable aircraft motion are the "half-amplitude" and the "double-amplitude" methods. The range of damping ratios determined by these methods is from -0.5 to +0.5. The damped natural frequencies were obtained by direct measurement of the period of oscillation and computed by the formula:

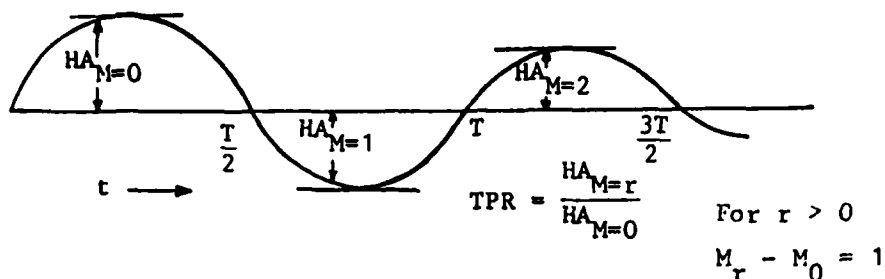
$$\omega_{\text{damped}} = \frac{1}{\tau}$$

Where:

ω_{damped} = Damped natural frequency (cycles/sec)

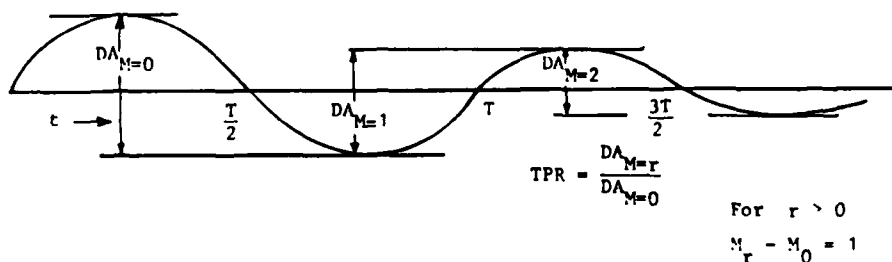
τ = The period of one oscillation from one peak to the next peak (sec)

The half-amplitude method requires that the initial steady-state value be known and that the steady state be constant. Once the steady-state value has been determined, the half-amplitudes are obtained by measuring the distance from the steady state to the maximum and minimum points of response.



Half-Amplitude Method

The double amplitude method also requires that the steady state be a constant, but if the double amplitudes are measured as shown below, the transient peak ratio can be obtained without having to establish the steady state or trim value of response.



Double-Amplitude Method

7. Roll mode time constant was determined as the time to achieve 63 percent of steady state roll rate.

AIRSPEED CALIBRATION

8. The ship's standard pitot-static system was calibrated using the pace aircraft method to determine the airspeed position error (fig. 52, app F). Calibrated airspeed (V_{cal}) was obtained by correcting indicated airspeed (V_i) for instrument error (ΔV_{ic}) and position error (ΔV_{pc}).

$$V_{cal} = V_i + \Delta V_{ic} + V_{pc} \quad (17)$$

9. Equivalent airspeed (V_e) was used to reduce the flight test data, as it is a direct measure of the free stream dynamic pressure (q).

$$V_e = V_{cal} + \Delta V_c$$

Where:

$$\Delta V_c \text{ is the compressibility correction, } q = 0.00339V_e^2$$

10. True airspeeds (V_T) were determined from the test altitude air density ratio (σ) and equivalent airspeed, as follows:

$$V_T = \frac{V_e}{\sqrt{\sigma}}$$

Weight and Balance

11. Prior to the start of flight tests, the aircraft was weighed to determine weight, and longitudinal and lateral center of gravity locations. The aircraft was weighed in the following configurations:

- a. Full oil, trapped fuel, no crew, and instrumentation.
- b. Full oil, full fuel, no crew, and instrumentation.
- c. Full oil, full fuel, crew, and instrumentation.
- d. Full oil, full fuel, no instrumentation, and no crew.

Rigging Check

12. Mechanical rigging of engine and flight controls was checked for compliance with applicable RAF and Lycoming documents.

DEFINITIONS

13. Results were categorized as deficiencies or shortcomings in accordance with the following definitions.

Deficiency

14. A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued, or indicates improper design or other cause of an item or part, which seriously impairs the equipment's operational capability. A deficiency normally disables or immobilizes the equipment; and if occurring during test phases, will serve as a bar to type classification action.

Shortcoming

15. An imperfection or malfunction occurring during the life cycle of equipment, which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product. If occurring during test phases, the shortcoming should be corrected if it can be done without unduly complicating the item or inducing another undesirable characteristic such as increase cost, weight, etc.

16. A Handling Qualities Rating Scale was used to augment pilot comments relative to handling qualities. This scale is presented in figure 1.

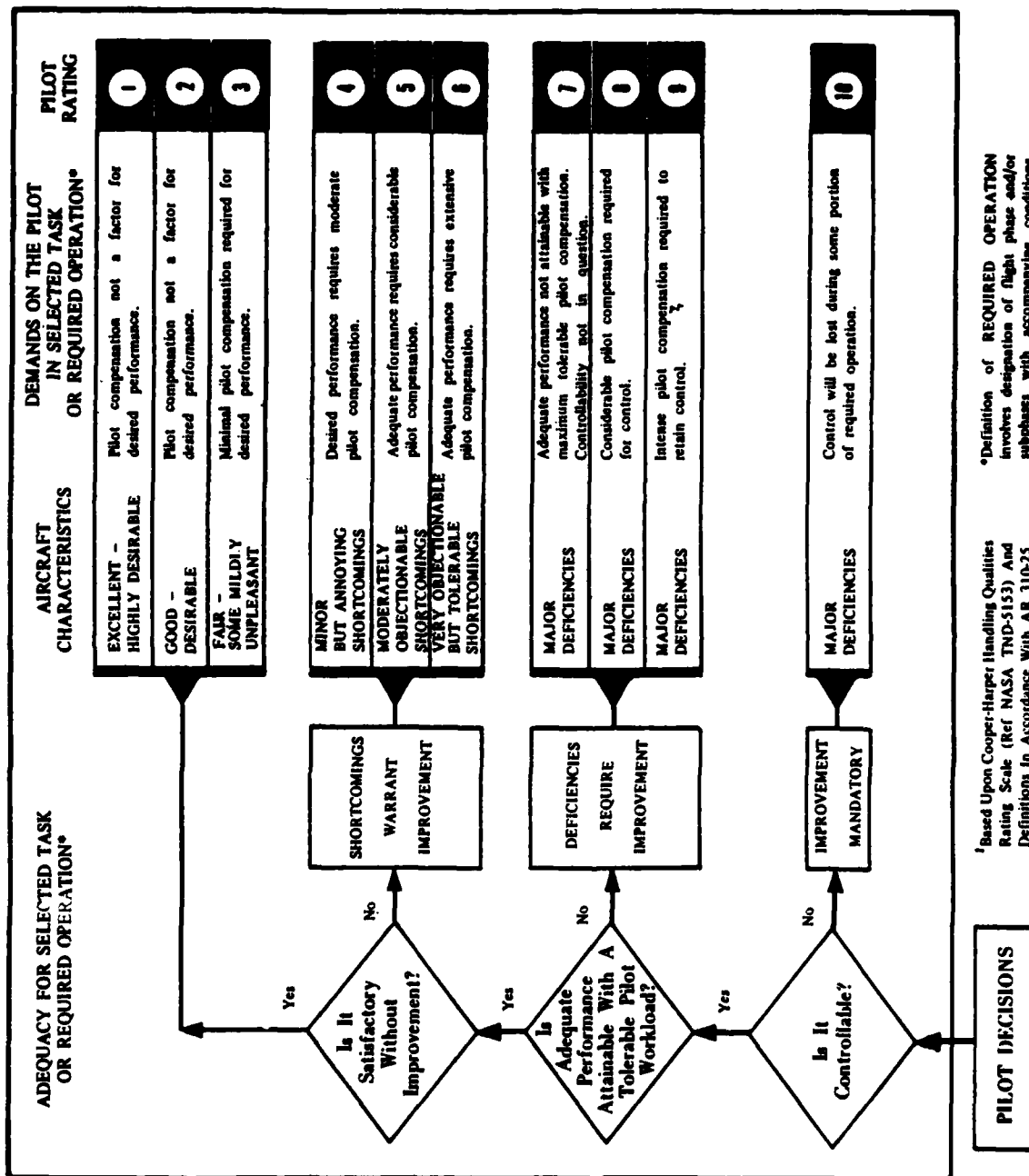


Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

<u>Figure</u>	<u>Figure No.</u>
Propeller Stopped Glide Drag Polar	1
Stall Performance	2 through 7
Accelerated Stall Performance	8 and 9
Control Positions in Trimmed Forward Flight	10 and 11
Static Longitudinal Stability	12 through 14
Static Lateral-Directional Stability	15 through 18
Maneuvering Stability	19 and 20
Phugoid	21
Longitudinal Short Period Response	22
Lateral-Directional Response	23 through 26
Gust Response	27
Roll Control Effectiveness	28 through 31
Takeoff Performance	32
Landing Performance	33
Vibration Characteristics	34 and 35
Vibration Spectrum	36
Vibration Characteristics	37 and 38
Vibration Spectrum	39
Vibration Characteristics	40 and 41
Vibration Spectrum	42
Airspeed Calibration	43

AVG GROSS WEIGHT (POUNDS)	PROPELLER STOPPED LONG-EZE USA 82-18	DRAG POLAR (CN1241)	AVG ALTITUDE (FEET)	AIRCRAFT CONFIGURATION
1320	AVG LONGITUDINAL CG LOCATION (FUS)	8700	85	CRUISE

NOTE: DASH LINES DERIVED FROM USAFPA PROJECT NO. 82-18, PRELIMINARY AIRWORTHINESS EVALUATION OF AN AIRCRAFT FACTORY CRAFT, INC. LONG-LEAF AIRPLANE, DATED JUNE 1988. FINAL REPORT.

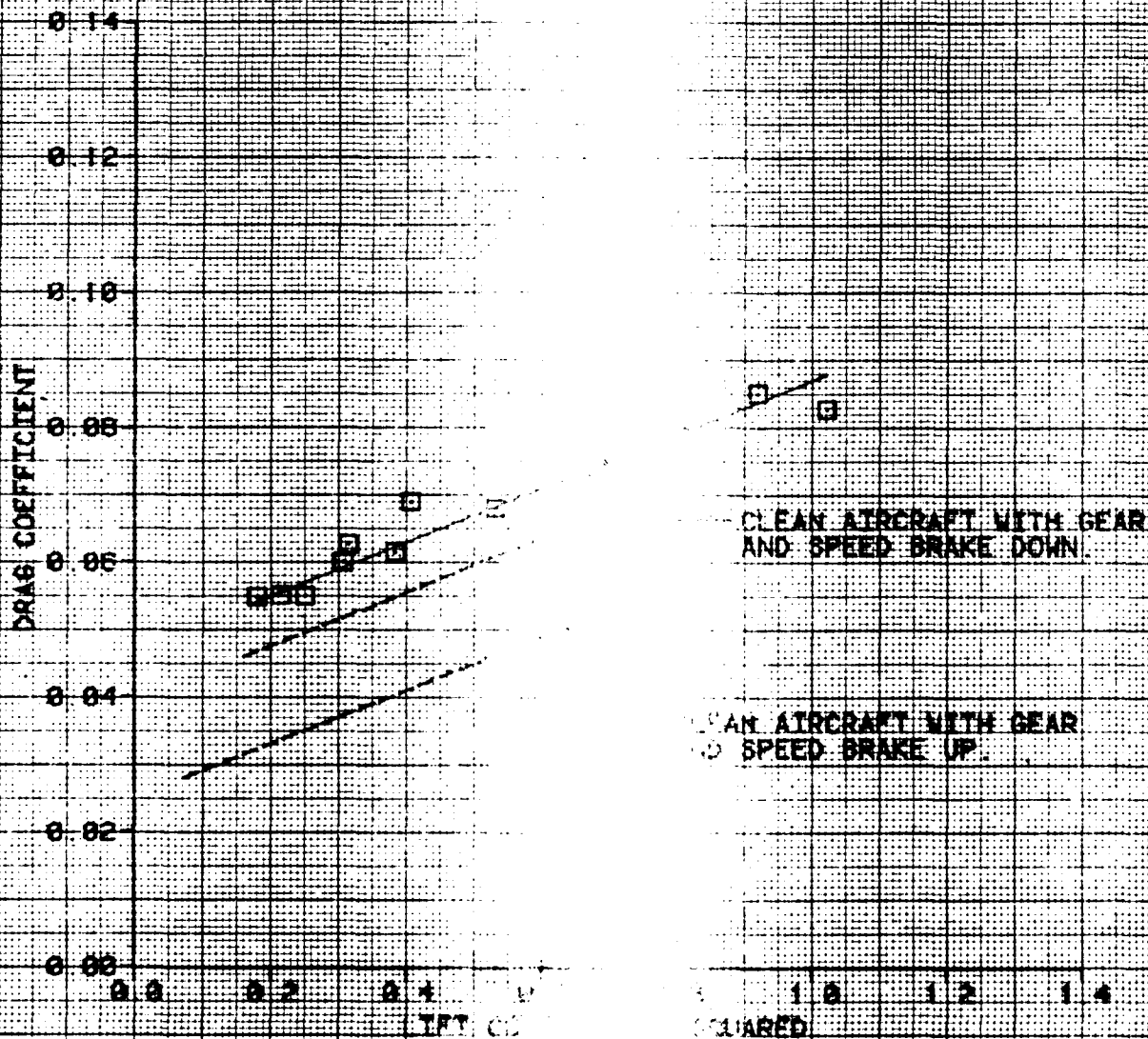


FIGURE 2
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (POUNDS) 1330
LONGITUDINAL CG LOCATION (FSD) 100.1 (MID)
DENSITY ALTITUDE (FEET) 8200
OAT (DEG C) -2.8
AIRCRAFT CONFIGURATION TAKEOFF

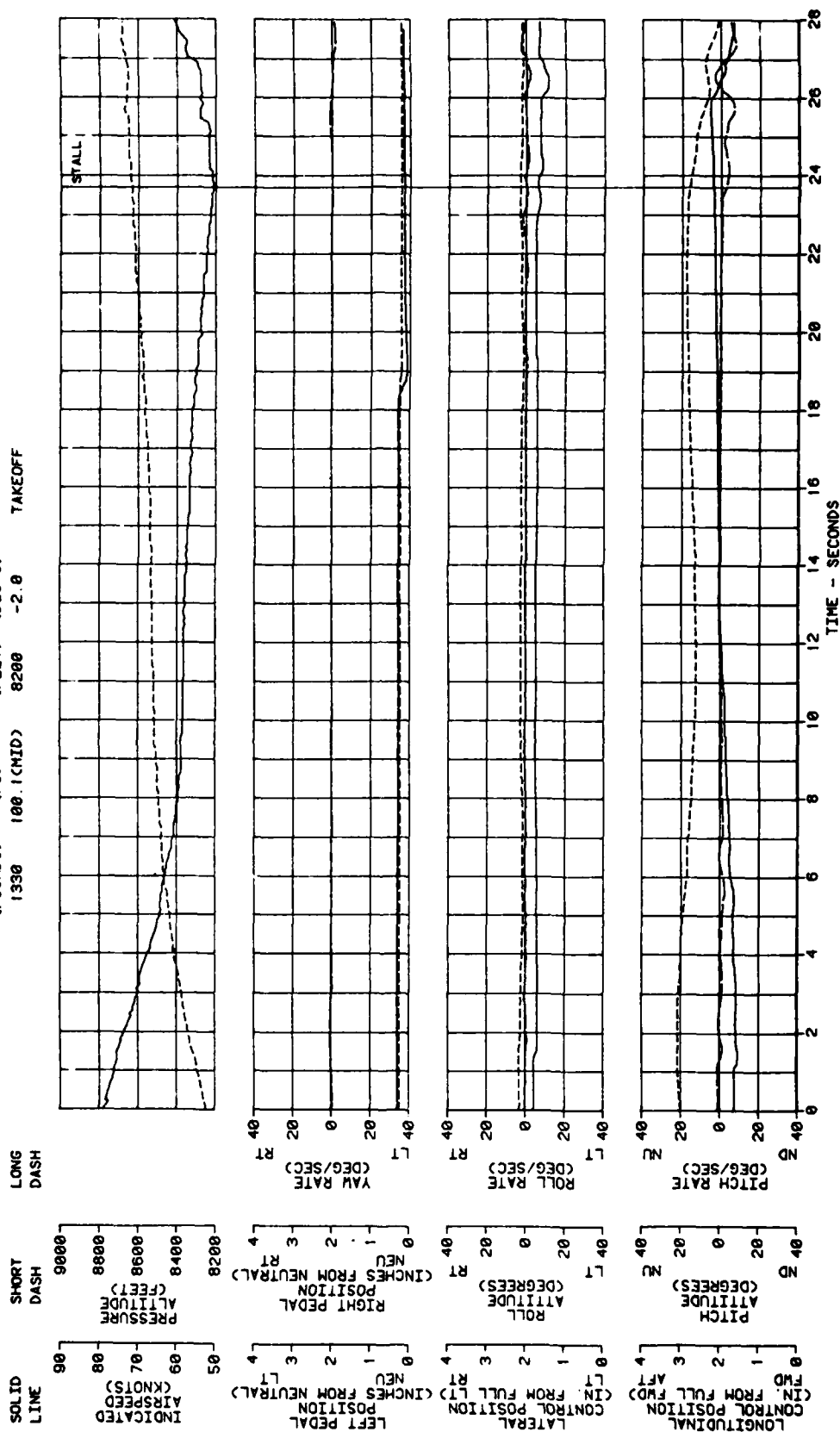


FIGURE 3
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (POUNDS) 1330
LONGITUDINAL CG LOCATION (IN) 100.1 (MID)
DENSITY ALTITUDE (FEET) 7920
AIRBORNE CONFIGURATION (DEG C) -1.0
CLIMB

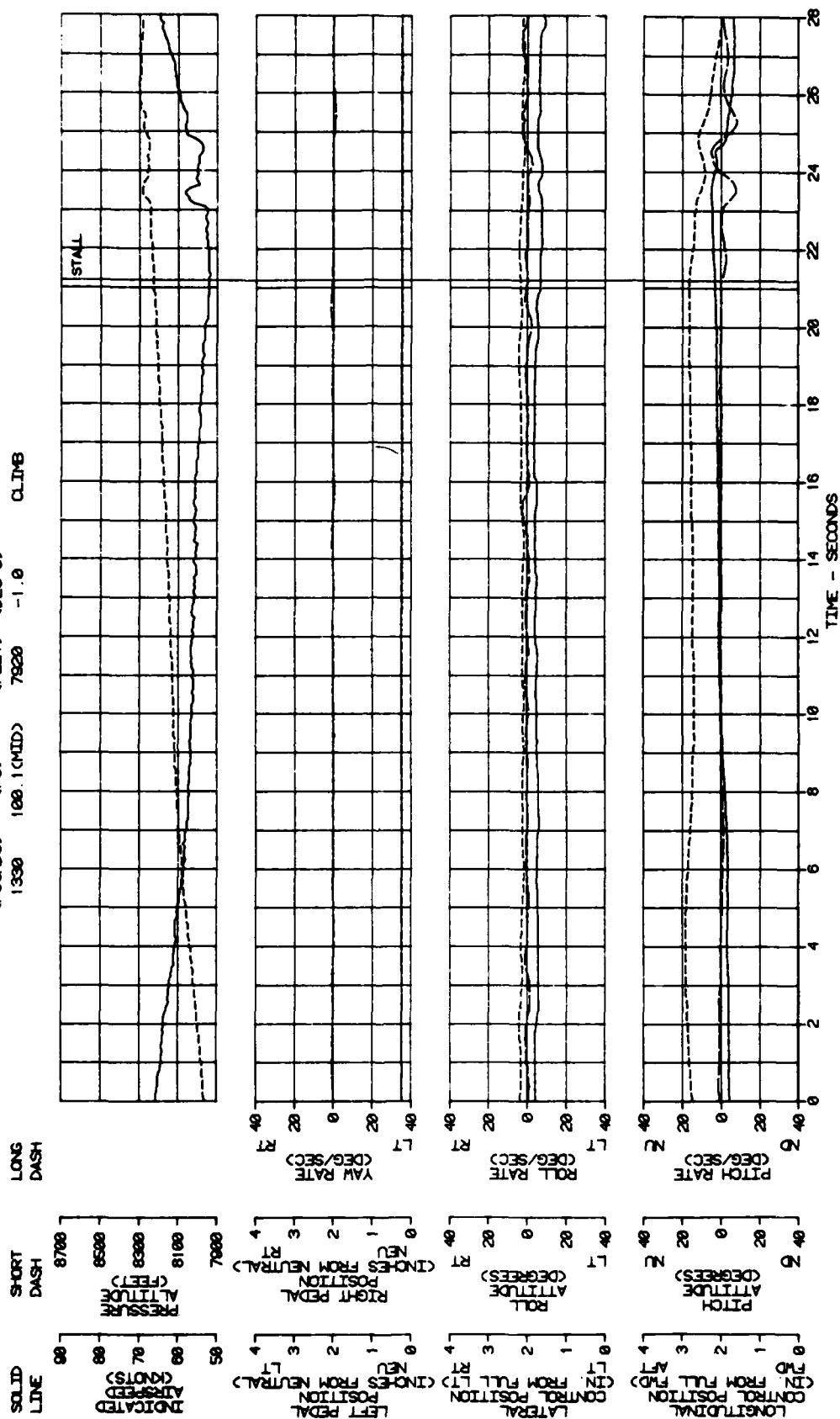


FIGURE 4
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
LONGITUDINAL DENSITY OAT
CG LOCATION ALTITUDE (DEG C) AIRCRAFT
WEIGHT (FS) 1330 100.1 (MID) 7820 -0.5 CONFIGURATION
CRUISE

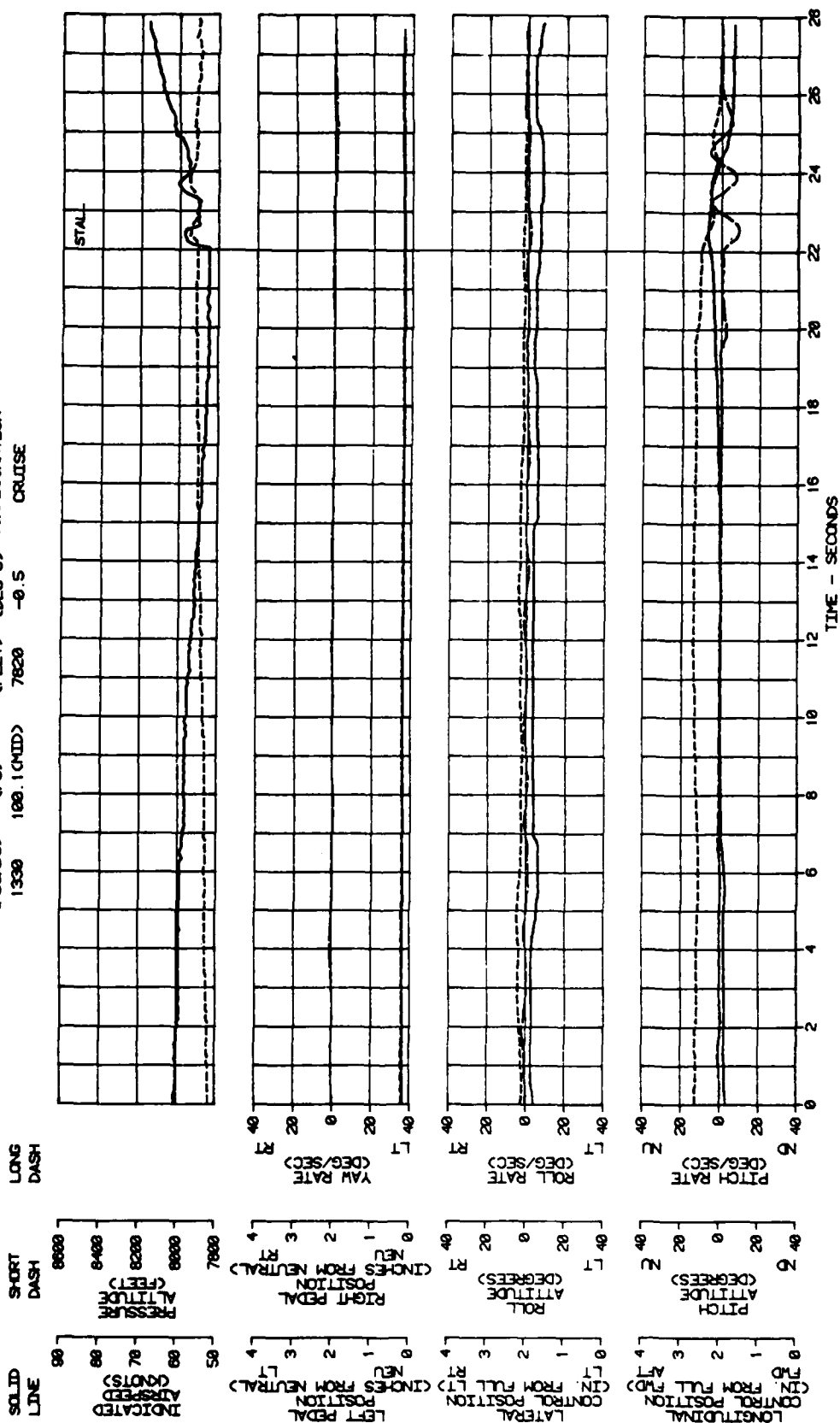


FIGURE 5
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
LONGITUDINAL DENSITY ALTITUDE (FEET)
GROSS WEIGHT (POUNDS) 1330 160.1 (MID) 7300 0.5 POWER APPROACH
AIRCRAFT CONFIGURATION (DEG C)

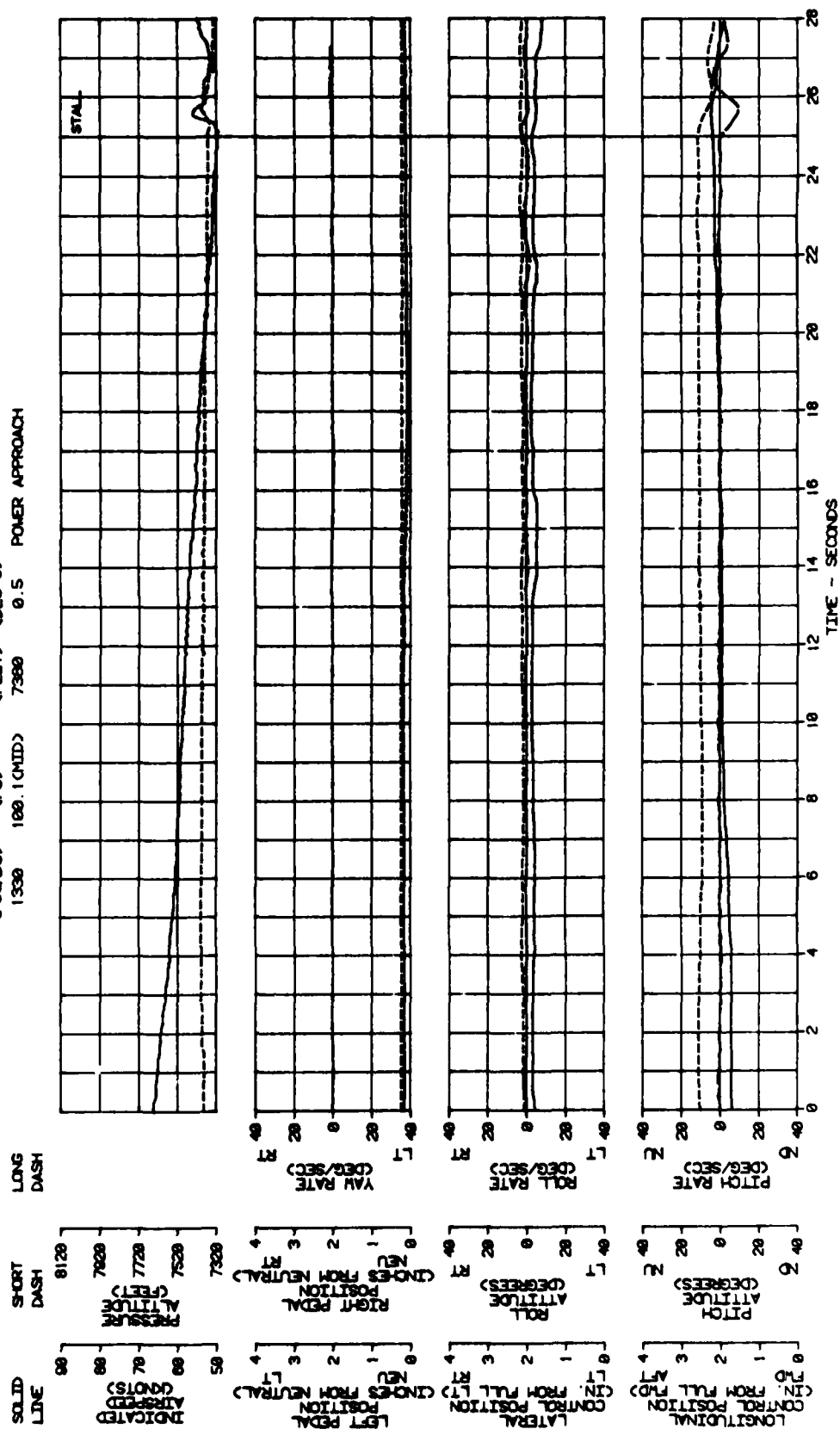


FIGURE 6
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (POUNDS) 13300
LONGITUDINAL CG LOCATION (FEET) 100.1 (MID)
DENSITY ALTITUDE (FEET) 7820
AIRFRAME CONFIGURATION (DEG C) -0.5
GLIDE

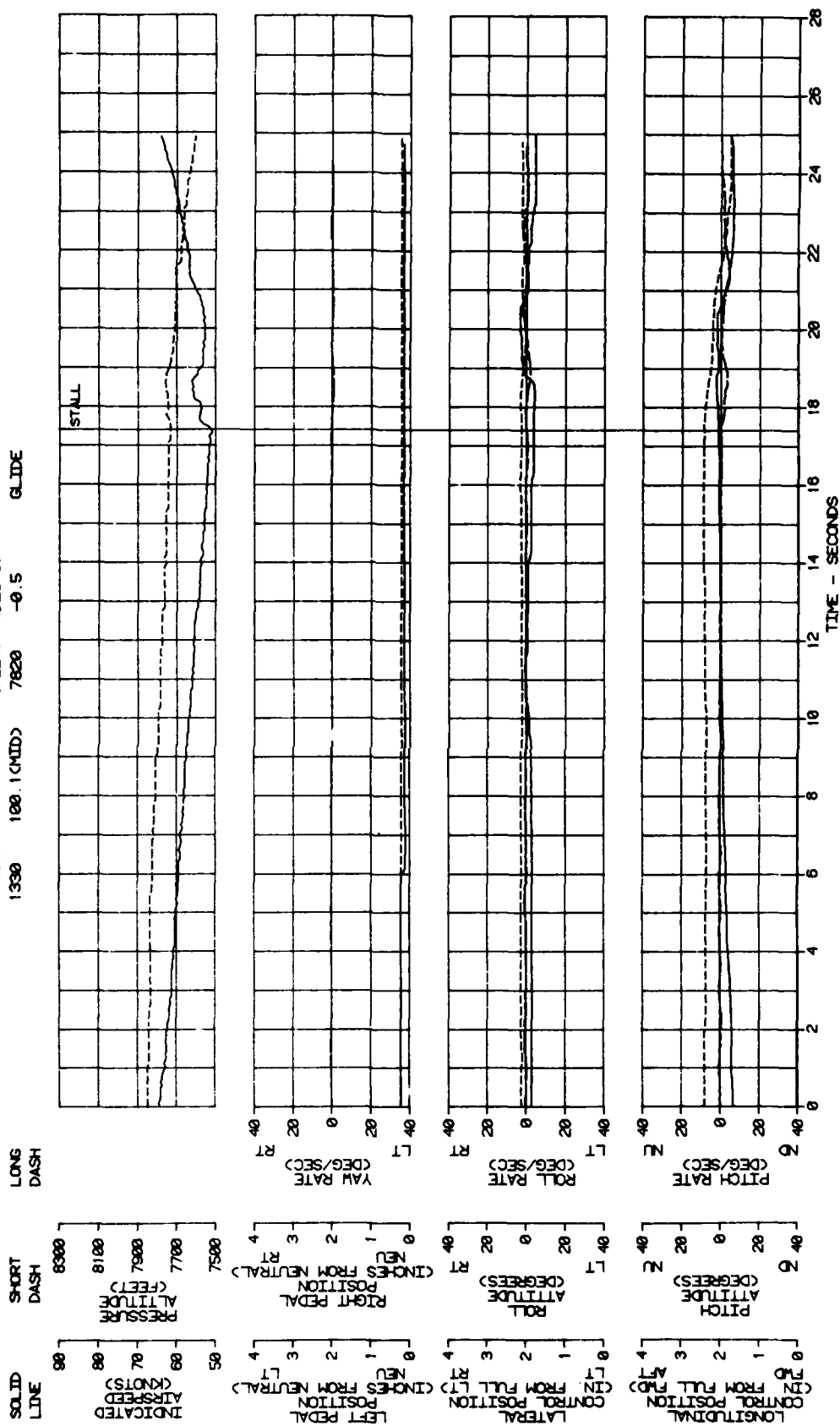


FIGURE 7
STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (POUNDS) 1330
LONGITUDINAL CG LOCATION (FSD) 100.1 (MID)
DENSITY ALTITUDE (FEET) 7740
OAT (DEG C) -1.0
AIRCRAFT CONFIGURATION LANDING

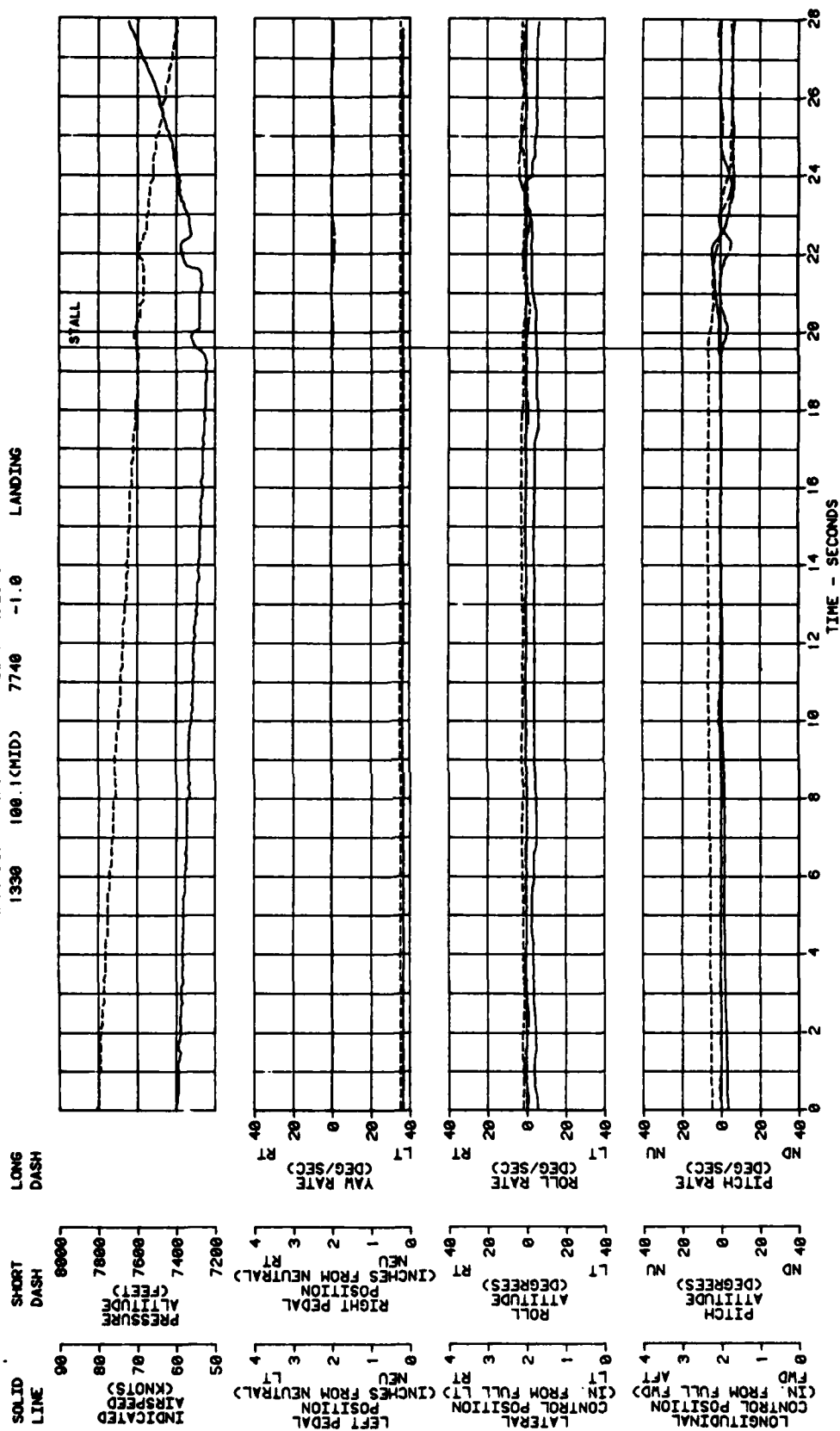


FIGURE 8
ACCELERATED STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (POUNDS) 1330
LONGITUDINAL CG LOCATION (FS) 100.1 (MID)
DENSITY ALTITUDE (FEET) 7480
OAT (DEG C) -0.5
AIRCRAFT CONFIGURATION CRUISE

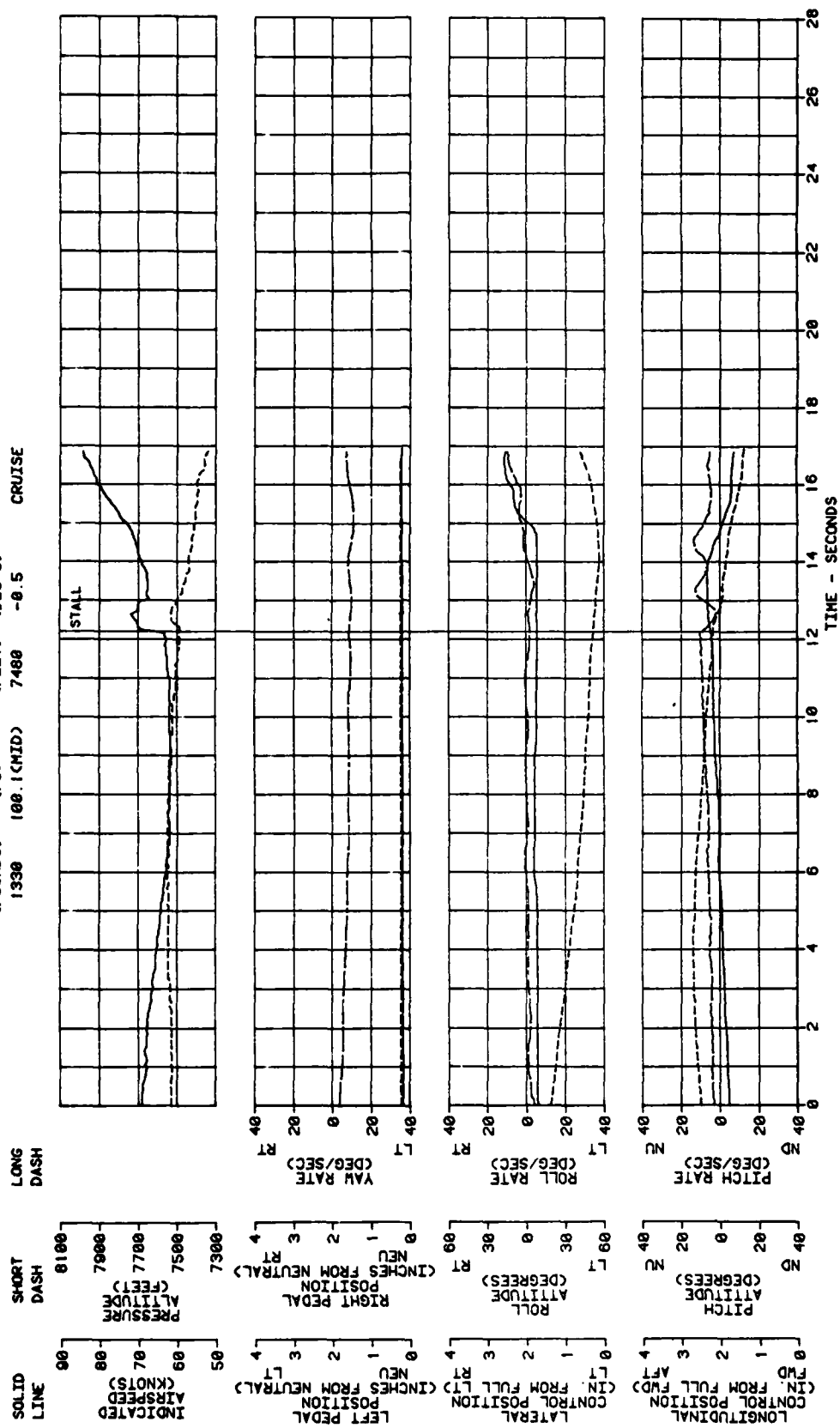
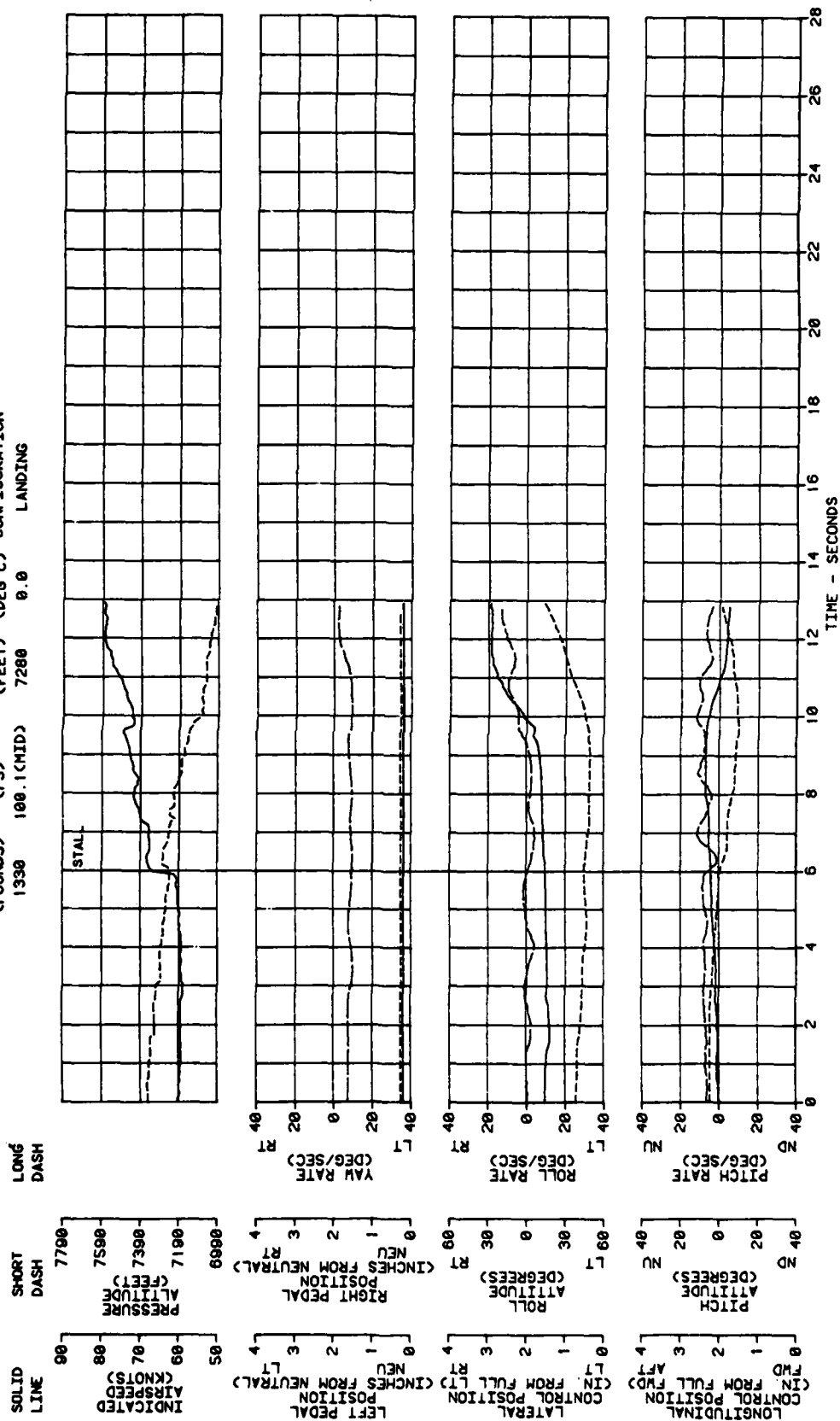


FIGURE 9
ACCELERATED STALL PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT 13300 (POUNDS)
LONGITUDINAL CG LOCATION 100.1 (INCHES)
DENSITY ALTITUDE 7280 (FEET)
OAT 0.0
AIRCRAFT CONFIGURATION LANDING



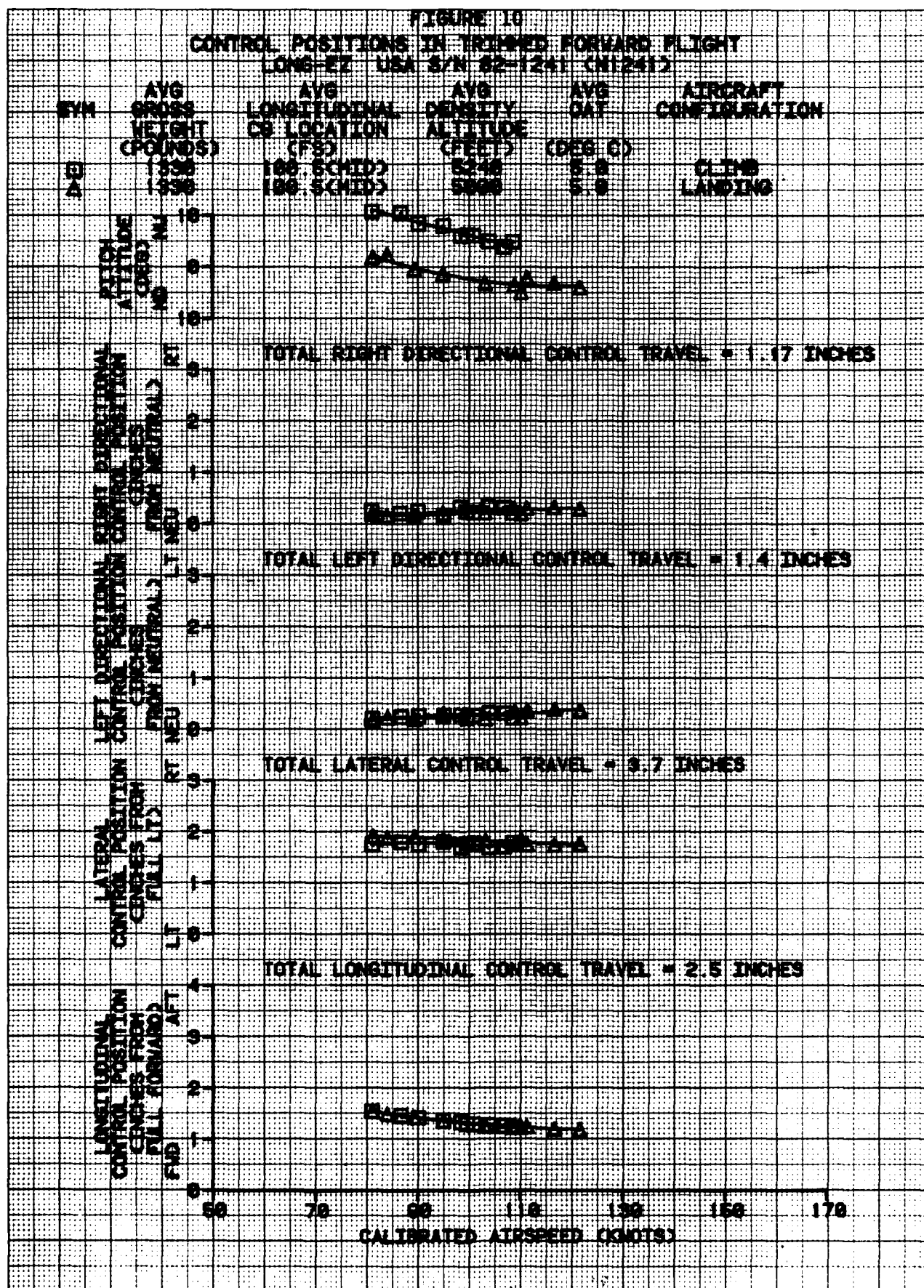


FIGURE 11

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
LONG-EZ USA S/N 82-1241 (N1241)

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (F8)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
□	1325	100.6 (MID)	4080	5.5	CRUISE
△	1305	101.1 (MID)	4980	5.0	CRUISE (DIVE)

PITCH ATTITUDE (DEG)

RIGHT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL) RT
LEFT DIRECTIONAL CONTROL POSITION (INCHES FROM NEUTRAL) LT

LATERAL CONTROL POSITION (INCHES FROM FULL LT) LT
LONGITUDINAL CONTROL POSITION (INCHES FROM FULL FWD) FWD

TOTAL RIGHT DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES

TOTAL LEFT DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES

TOTAL LATERAL CONTROL TRAVEL = 3.7 INCHES

TOTAL LONGITUDINAL CONTROL TRAVEL = 2.5 INCHES

CALIBRATED AIRSPEED (KNOTS)

FIGURE 12

STATIC LONGITUDINAL STABILITY

LONG-EZ USA S/N 82-1241 (N1241)

AVG GROSS WEIGHT (POUNDS) 1335	AVG LONGITUDINAL CG LOCATION (INCHES) 100.1 (MID)	AVG DENSITY ALTITUDE (FEET) 6380	AVG OAT (DEG C) 4.0	TRIM CALIBRATED AIRSPEED (KNOTS) 97	AIRCRAFT CONFIGURATION CLIMB
--	---	--	------------------------------	---	------------------------------------

NOTE: Shaded symbol denotes trim

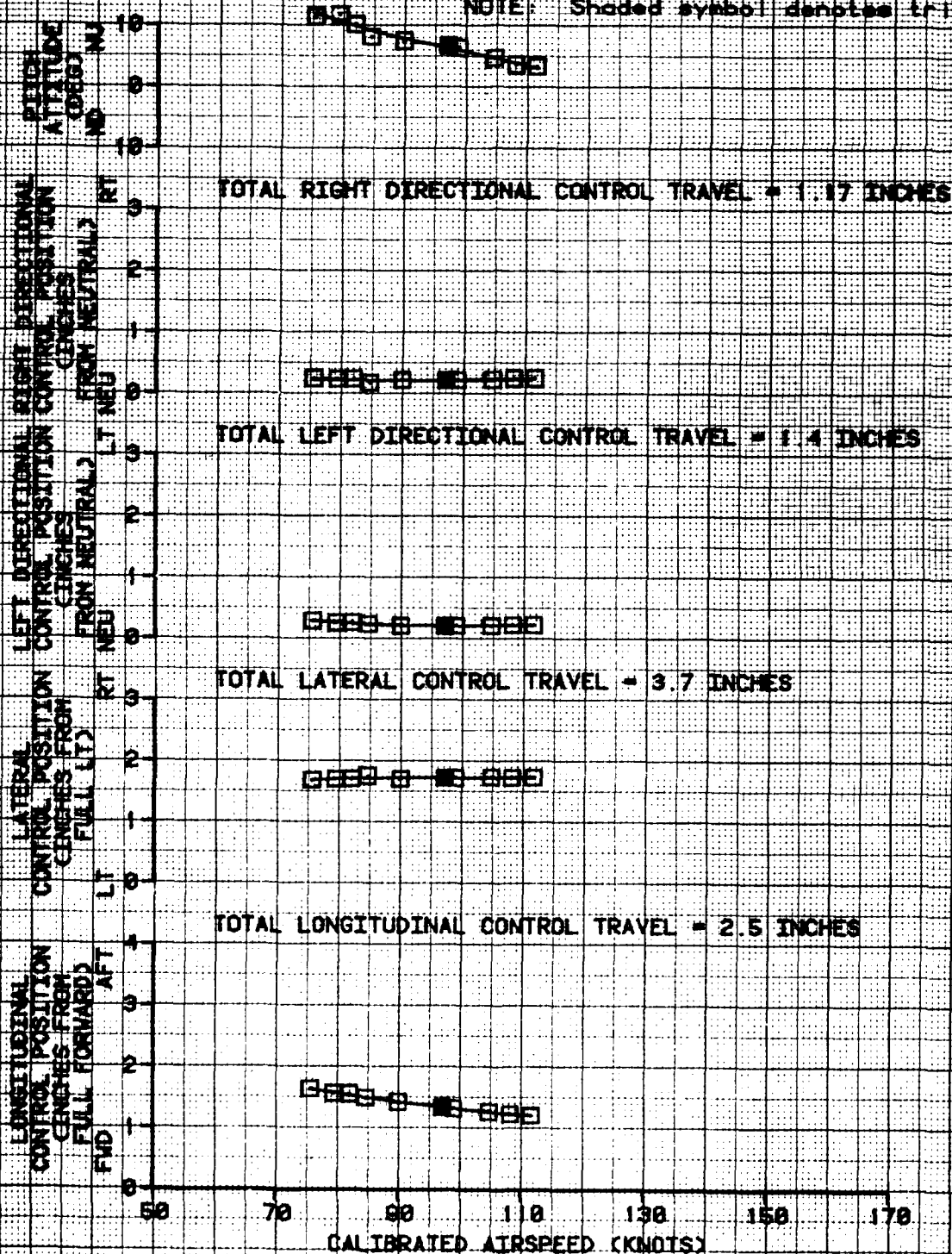


FIGURE 13

STATIC LONGITUDINAL STABILITY
LONG-EZ USA S/N 82-1241 (N1241)

AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (IN)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	TRIM CALIBRATED AIRSPEED (KNOTS)	AIRCRAFT CONFIGURATION
1350	100.3 (MID)	5300	5.5	115	CRUISE

NOTE: Shaded symbol denotes trim.

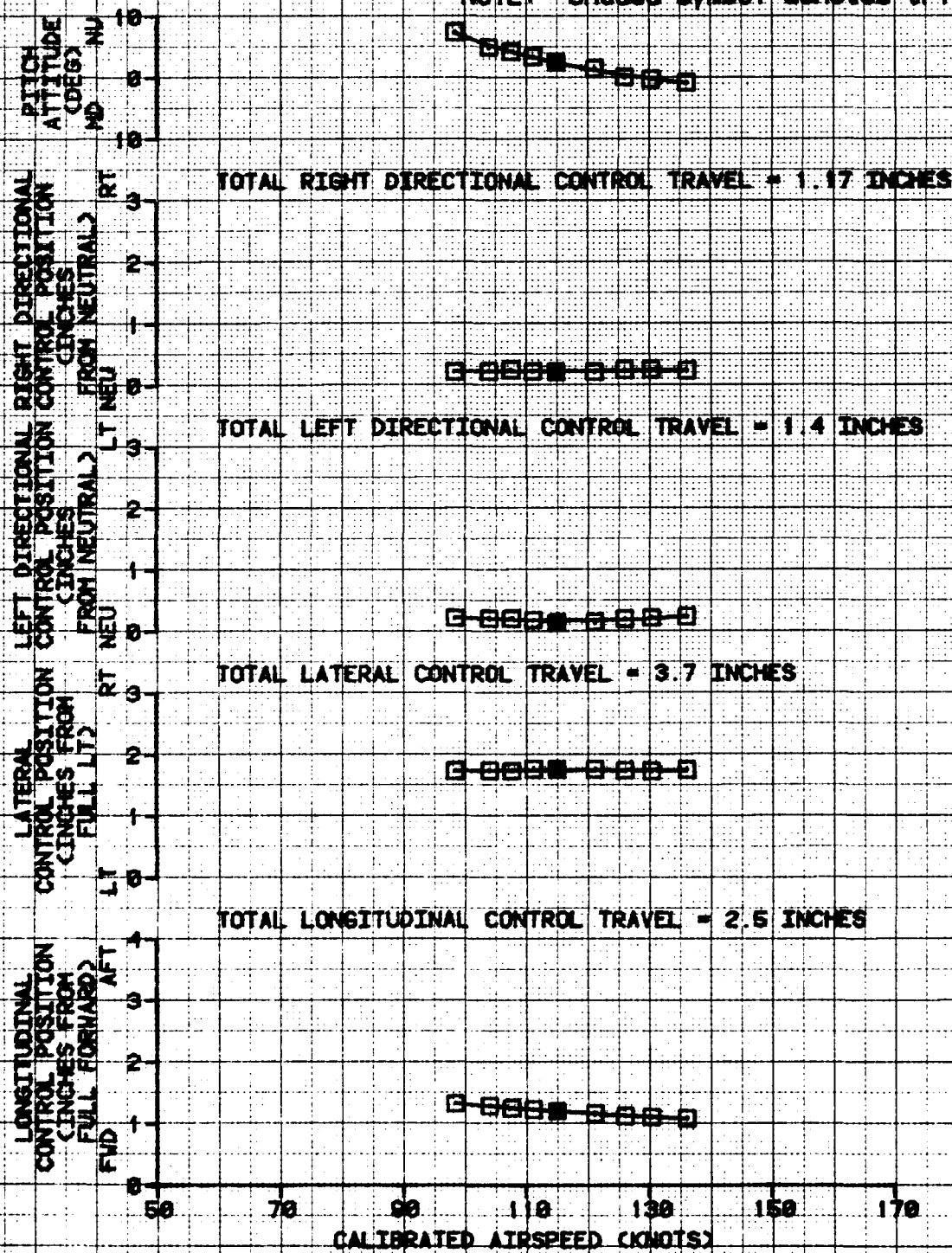


FIGURE 14
 STATIC LONGITUDINAL STABILITY
 LONG-EZ USA S/N 82-1241 (N1241)

AVG GROSS HEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FUS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	TRIM CALIBRATED AIRSPEED (KNOTS)	AIRCRAFT CONFIGURATION
1345	100.2 (MID)	4880	3.6	84	LANDING

NOTE: Shaded symbol denotes trim.

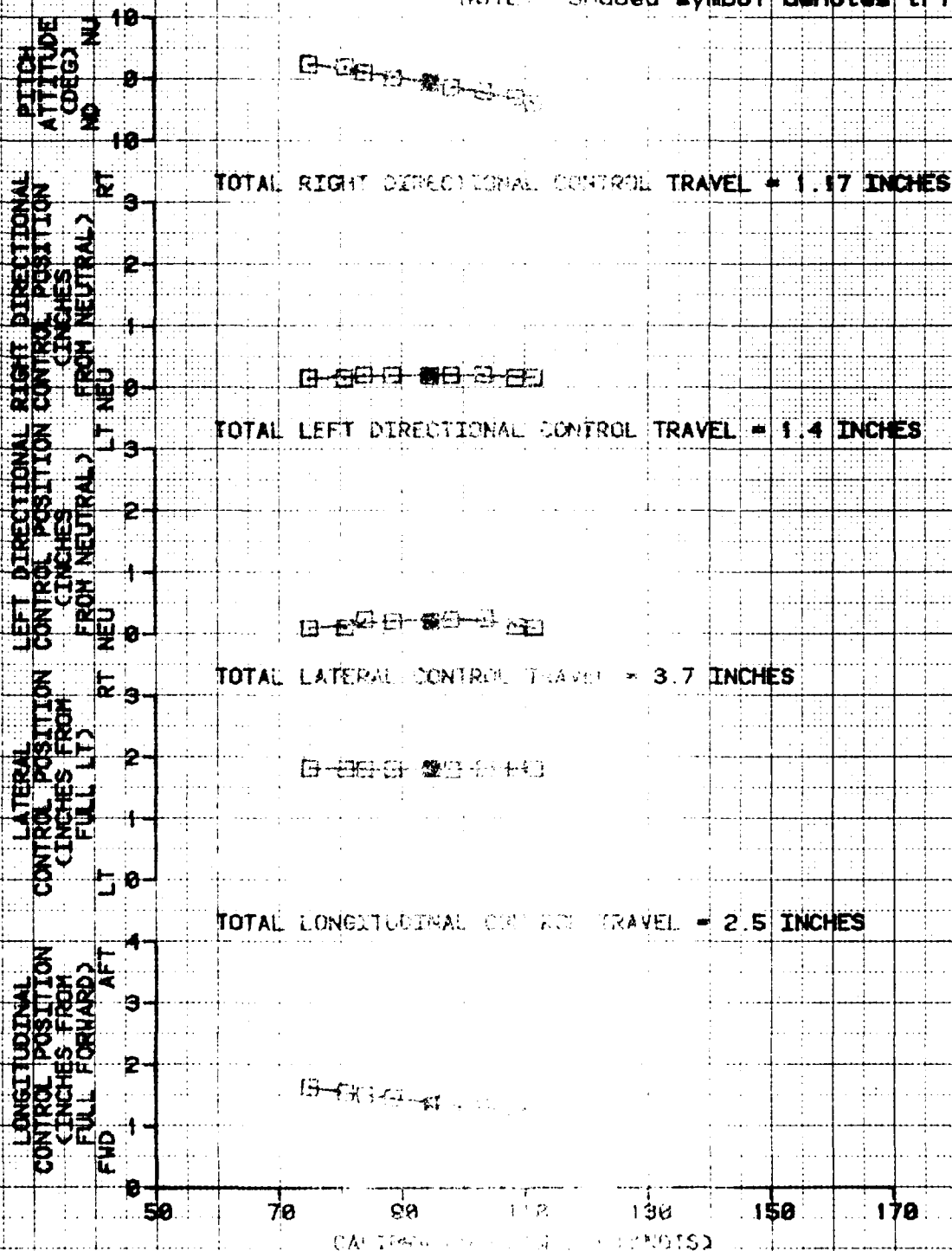


FIGURE 15
 STATIC LATERAL-DIRECTIONAL STABILITY
 LORNG-CE USA 9/11 52-1241 (N1241)

AVG
GROSS
WEIGHT
(POUNDS)
1534

AVG
CG LOCATION
(FEET)
100.6 (NED)

AVG
DENSITY
ALTITUDE
(FEET)
1000

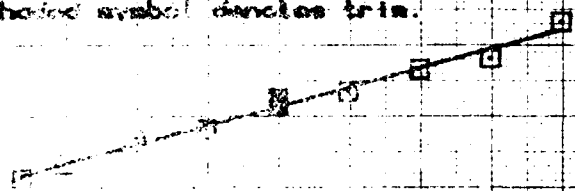
AVG
OAT
(DEG C)
8.6

TRIM
CALIBRATED
AIRSPEED
(KNOTS)
68

AIRCRAFT
CONFIGURATION
CLIMB

NOTE: Shaded symbol denotes trim.

ROLL
ATTITUDE
(DEG)
18
24
30



RIGHT AILERON DIRECTIONAL CONTROL TRAVEL = 1.17 INCHES

RIGHT
DIRECTIONAL
CONTROL
POSITION
(INCHES)
0
1
2
3



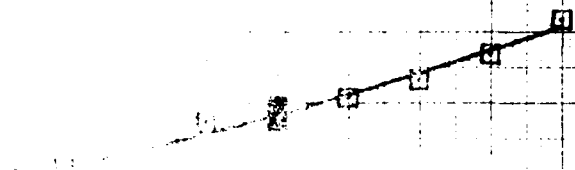
LEFT AILERON DIRECTIONAL CONTROL TRAVEL = 1.4 INCHES

LEFT
DIRECTIONAL
CONTROL
POSITION
(INCHES)
0
1
2
3



RIGHT ROLL CONTROL TRAVEL = 3.7 INCHES

LATERAL
CONTROL
POSITION
(INCHES)
0
1
2
3



LEFT ROLL CONTROL TRAVEL = 2.5 INCHES

POSITIONAL
CONTROL POSITION
(INCHES)
0
1
2
3



Yaw Attitude (DEGREES) RIGHT

FIGURE 16
STATIC LATERAL-DIRECTIONAL STABILITY
 (END-2) (REF. 24) (24) (24)

AIR SPEED (KNOTS)	AIR SPEED (KNOTS)	AIR SPEED (KNOTS)	AIR SPEED (KNOTS)	TEMP CALCULATED (KNOTS)	AIRCRAFT CONFIGURATION
150	150	150	150	150	CRUISE

NOTE: (a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r) (s) (t) (u) (v) (w) (x) (y) (z) (aa) (ab) (ac) (ad) (ae) (af) (ag) (ah) (ai) (aj) (ak) (al) (am) (an) (ao) (ap) (aq) (ar) (as) (at) (au) (av) (aw) (ax) (ay) (az) (ba) (bb) (bc) (bd) (be) (bf) (bg) (bh) (bi) (bj) (bk) (bl) (bm) (bn) (bo) (bp) (bq) (br) (bs) (bt) (bu) (bv) (bw) (bx) (by) (bz) (ca) (cb) (cc) (cd) (ce) (cf) (cg) (ch) (ci) (cj) (ck) (cl) (cm) (cn) (co) (cp) (cq) (cr) (cs) (ct) (cu) (cv) (cw) (cx) (cy) (cz) (da) (db) (dc) (dd) (de) (df) (dg) (dh) (di) (dj) (dk) (dl) (dm) (dn) (do) (dp) (dq) (dr) (ds) (dt) (du) (dv) (dw) (dx) (dy) (dz) (ea) (eb) (ec) (ed) (ee) (ef) (eg) (eh) (ei) (ej) (ek) (el) (em) (en) (eo) (ep) (eq) (er) (es) (et) (eu) (ev) (ew) (ex) (ey) (ez) (fa) (fb) (fc) (fd) (fe) (ff) (fg) (fh) (fi) (fj) (fk) (fl) (fm) (fn) (fo) (fp) (fq) (fr) (fs) (ft) (fu) (fv) (fw) (fx) (fy) (fz) (ga) (gb) (gc) (gd) (ge) (gf) (gg) (gh) (gi) (gj) (gk) (gl) (gm) (gn) (go) (gp) (gq) (gr) (gs) (gt) (gu) (gv) (gw) (gx) (gy) (gz) (ha) (hb) (hc) (hd) (he) (hf) (hg) (hh) (hi) (hj) (hk) (hl) (hm) (hn) (ho) (hp) (hq) (hr) (hs) (ht) (hu) (hv) (hw) (hx) (hy) (hz) (ia) (ib) (ic) (id) (ie) (if) (ig) (ih) (ii) (ij) (ik) (il) (im) (in) (io) (ip) (iq) (ir) (is) (it) (iu) (iv) (iw) (ix) (iy) (iz) (ja) (jb) (jc) (jd) (je) (jf) (jg) (jh) (ji) (jj) (jk) (jl) (jm) (jn) (jo) (jp) (jq) (jr) (js) (jt) (ju) (jv) (jw) (jx) (jy) (jz) (ka) (kb) (kc) (kd) (ke) (kf) (kg) (kh) (ki) (kj) (kk) (kl) (km) (kn) (ko) (kp) (kq) (kr) (ks) (kt) (ku) (kv) (kw) (kx) (ky) (kz) (la) (lb) (lc) (ld) (le) (lf) (lg) (lh) (li) (lj) (lk) (ll) (lm) (ln) (lo) (lp) (lq) (lr) (ls) (lt) (lu) (lv) (lw) (lx) (ly) (lz) (ma) (mb) (mc) (md) (me) (mf) (mg) (mh) (mi) (mj) (mk) (ml) (mm) (mn) (mo) (mp) (mq) (mr) (ms) (mt) (mu) (mv) (mw) (mx) (my) (mz) (na) (nb) (nc) (nd) (ne) (nf) (ng) (nh) (ni) (nj) (nk) (nl) (nm) (nn) (no) (np) (nq) (nr) (ns) (nt) (nu) (nv) (nw) (nx) (ny) (nz) (oa) (ob) (oc) (od) (oe) (of) (og) (oh) (oi) (oj) (ok) (ol) (om) (on) (oo) (op) (oq) (or) (os) (ot) (ou) (ov) (ow) (ox) (oy) (oz) (pa) (pb) (pc) (pd) (pe) (pf) (pg) (ph) (pi) (pj) (pk) (pl) (pm) (pn) (po) (pp) (pq) (pr) (ps) (pt) (pu) (pv) (pw) (px) (py) (pz) (qa) (qb) (qc) (qd) (qe) (qf) (qg) (qh) (qi) (qj) (qk) (ql) (qm) (qn) (qo) (qp) (qq) (qr) (qs) (qt) (qu) (qv) (qw) (qx) (qy) (qz) (ra) (rb) (rc) (rd) (re) (rf) (rg) (rh) (ri) (rj) (rk) (rl) (rm) (rn) (ro) (rp) (rq) (rr) (rs) (rt) (ru) (rv) (rw) (rx) (ry) (rz) (sa) (sb) (sc) (sd) (se) (sf) (sg) (sh) (si) (sj) (sk) (sl) (sm) (sn) (so) (sp) (sq) (sr) (ss) (st) (su) (sv) (sw) (sx) (sy) (sz) (ta) (tb) (tc) (td) (te) (tf) (tg) (th) (ti) (tj) (tk) (tl) (tm) (tn) (to) (tp) (tq) (tr) (ts) (tt) (tu) (tv) (tw) (tx) (ty) (tz) (ua) (ub) (uc) (ud) (ue) (uf) (ug) (uh) (ui) (uj) (uk) (ul) (um) (un) (uo) (up) (uq) (ur) (us) (ut) (uu) (uv) (uw) (ux) (uy) (uz) (va) (vb) (vc) (vd) (ve) (vf) (vg) (vh) (vi) (vj) (vk) (vl) (vm) (vn) (vo) (vp) (vq) (vr) (vs) (vt) (vu) (vv) (vw) (vx) (vy) (vz) (wa) (wb) (wc) (wd) (we) (wf) (wg) (wh) (wi) (wj) (wk) (wl) (wm) (wn) (wo) (wp) (wq) (wr) (ws) (wt) (wu) (wv) (ww) (wx) (wy) (wz) (xa) (xb) (xc) (xd) (xe) (xf) (xg) (xh) (xi) (xj) (xk) (xl) (xm) (xn) (xo) (xp) (xq) (xr) (xs) (xt) (xu) (xv) (xw) (xx) (xy) (xz) (ya) (yb) (yc) (yd) (ye) (yf) (yg) (yh) (yi) (yj) (yk) (yl) (ym) (yn) (yo) (yp) (yq) (yr) (ys) (yt) (yu) (yv) (yw) (yx) (yy) (yz) (za) (zb) (zc) (zd) (ze) (zf) (zg) (zh) (zi) (zj) (zk) (zl) (zm) (zn) (zo) (zp) (zq) (zr) (zs) (zt) (zu) (zv) (zw) (zx) (zy) (zz)

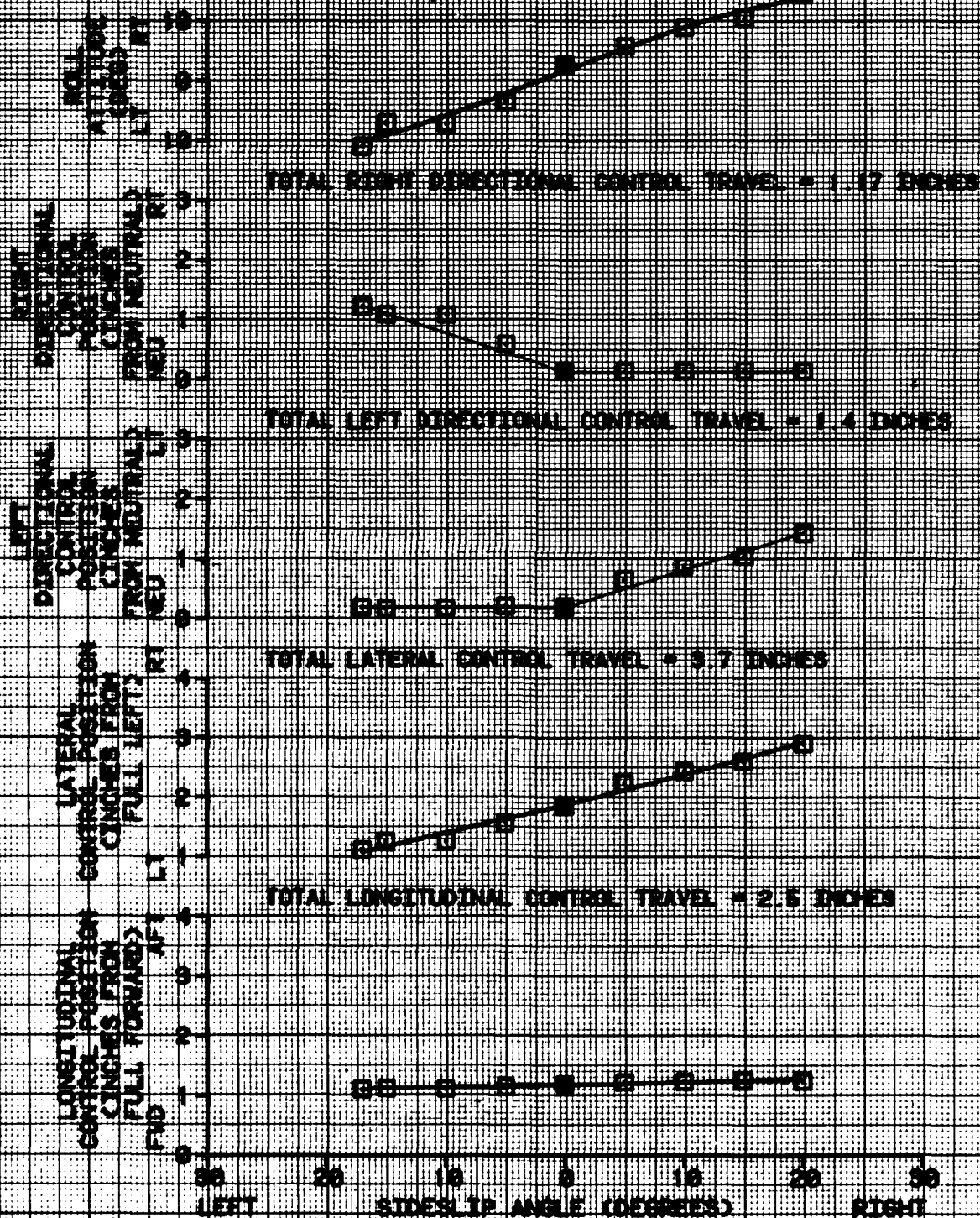


FIGURE 17
 STATIC LATERAL-DIRECTIONAL STABILITY
 LONG-CZ USA 57N 82-1241 (N1241)

AVG GROSS WEIGHT (POUNDS) 1826	AVG LONGITUDINAL CG LOCATION (F3) 100.04 (IN)	AVG DENSITY ALTITUDE (FEET) 4540	AVG DAY CALIBRATED AIRSPEED (KNOTS) 150	TRIM CALIBRATED AIRSPEED (KNOTS) 150	AIRCRAFT CONFIGURATION CRUISE
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NOTE: Shaded symbol denotes 1/2 in.

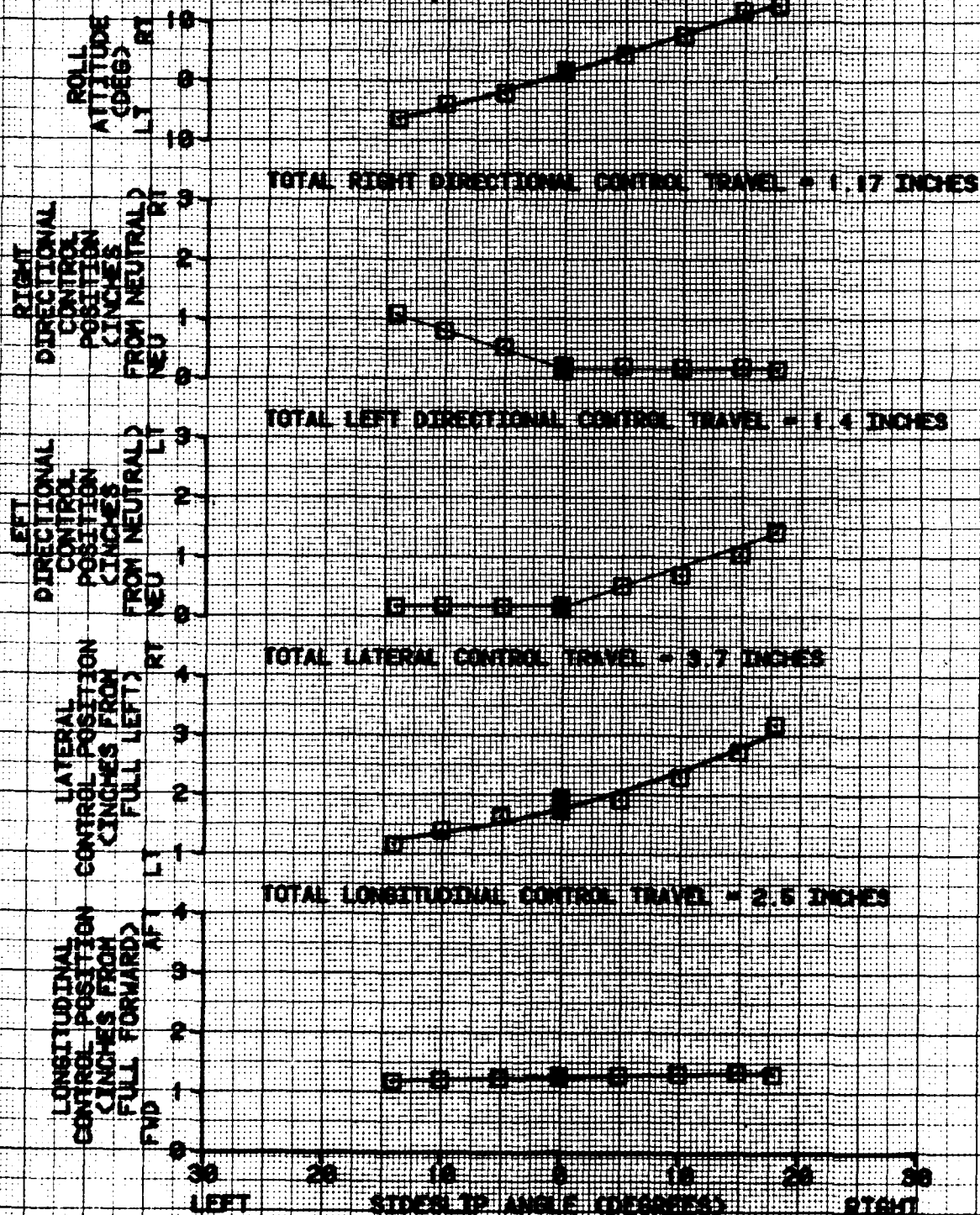


FIGURE 18
STATIC LATERAL-DIRECTIONAL STABILITY
LONG-17 USA S/N 82-1241 (N1241)

AVG	AVG	AVG	AVG	TRIM	AIRCRAFT
WEIGHT	LONGITUDINAL	DENSITY	QAT	CALIBRATED	CONFIGURATION
(POUNDS)	LOCATION	(FEET)	(DEG C)	AIRSPED	
1320	100.0000	8880	0.10	04	LANDING

NOTE: Shaded symbol denotes 1-in.

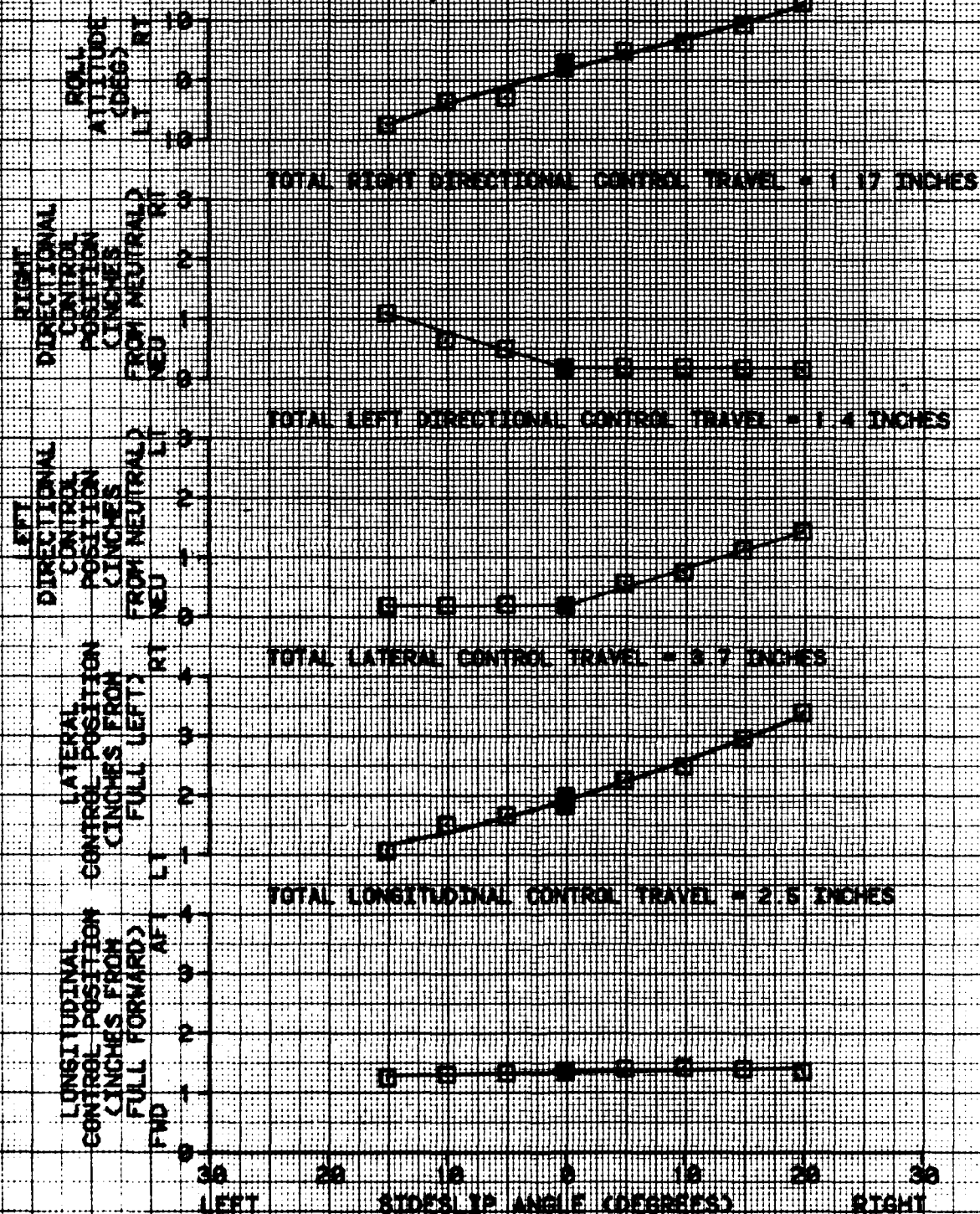


FIGURE 10 MANEUVERING STABILITY

LONG-EZ USA S/N 82-1241 CN 2413

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (CFS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	TRIM CALIBRATED AIRSPEED (KNOTS)	FLIGHT CONDITION
□	1358	100.2 (MID)	7660	-0.5	96	TURNS
△	1340	100.2 (MID)	7620	-1.5	104	PULLUP/PUSHOVER

NOTES: 1 CRUISE CONFIGURATION
2 SHADED SYMBOL DENOTES TRIM.

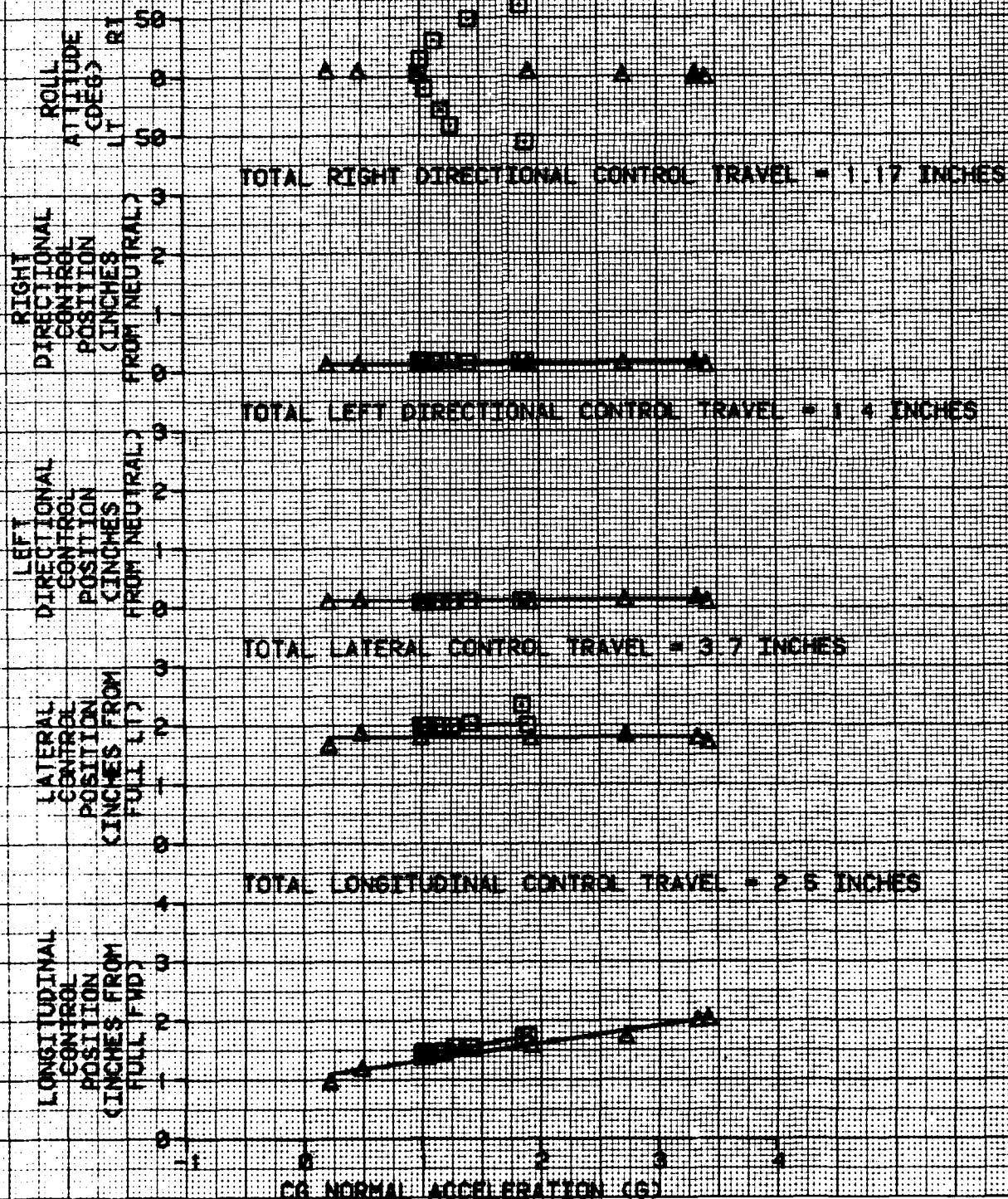


FIGURE 28

MANEUVERING STARTILITY

LONG-EZ USA S/N 62-1241 (N1241)

Avg SINK RATE (FOOT/S)	Avg LONGITUDINAL IN LOCATION (FT)	Avg DENSITY ALTITUDE (FEET)	Avg DIT (DEG)	TRIM CALCULATED AIRSPEED (KNOTS)	FLIGHT CONDITION
1300	100 (400)	7140	0.5	100	TURN

- NOTES: 1 CRUISE CONFIGURATION
2 SHADED SYMBOL DENOTES TRIM

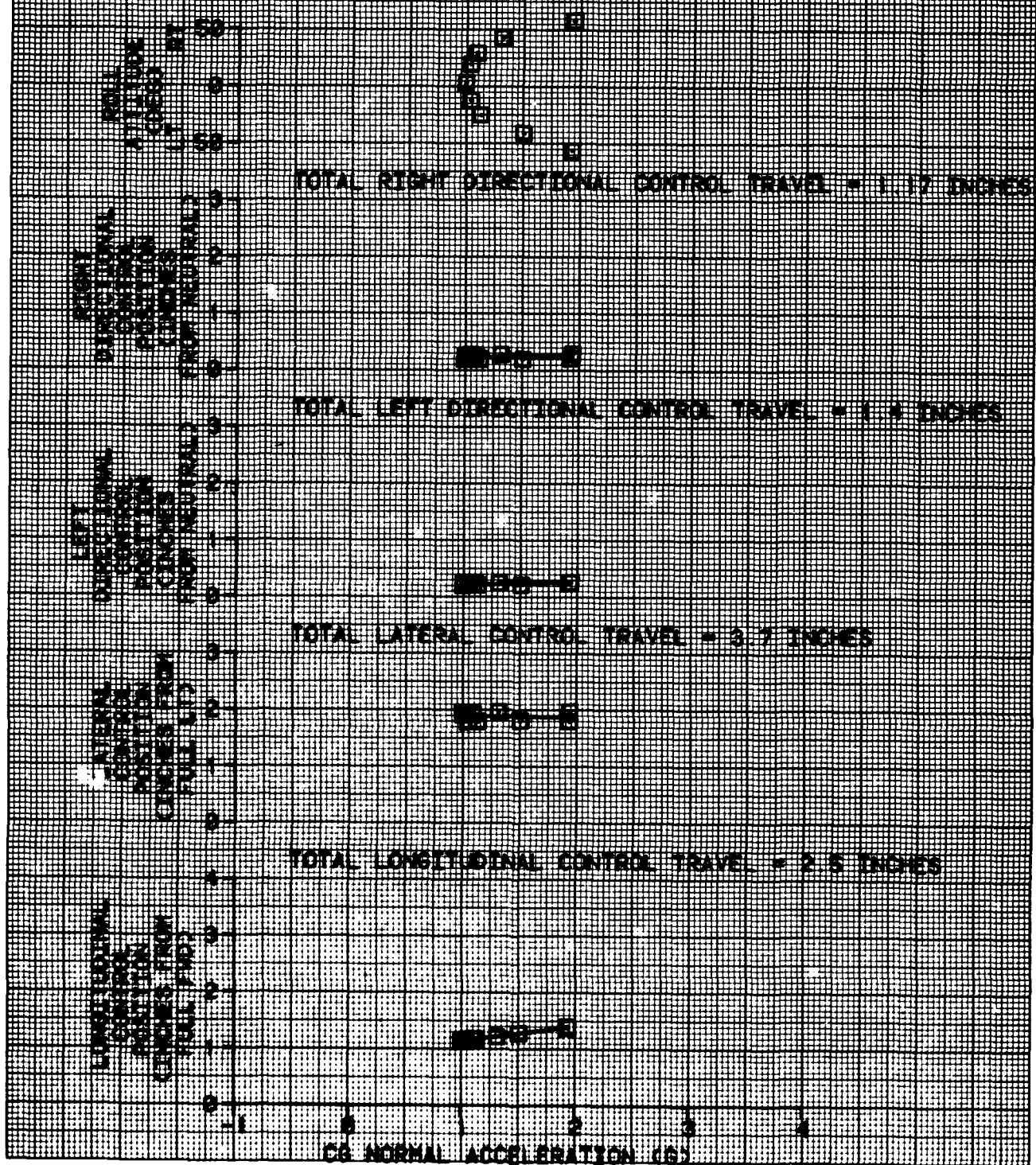


FIGURE 21
 PHUGOID
 LONG-EZ USA S/N 82-1241 (N1241)
 LONGITUDINAL DENSITY DAT AIRCRAFT
 GROSS WEIGHT CG LOCATION ALTITUDE OAT CONFIGURATION
 (POUNDS) (FPS) (FEET) (DEG C)
 1330 101.1 (N1241) 7500 -2.5 CRUISE

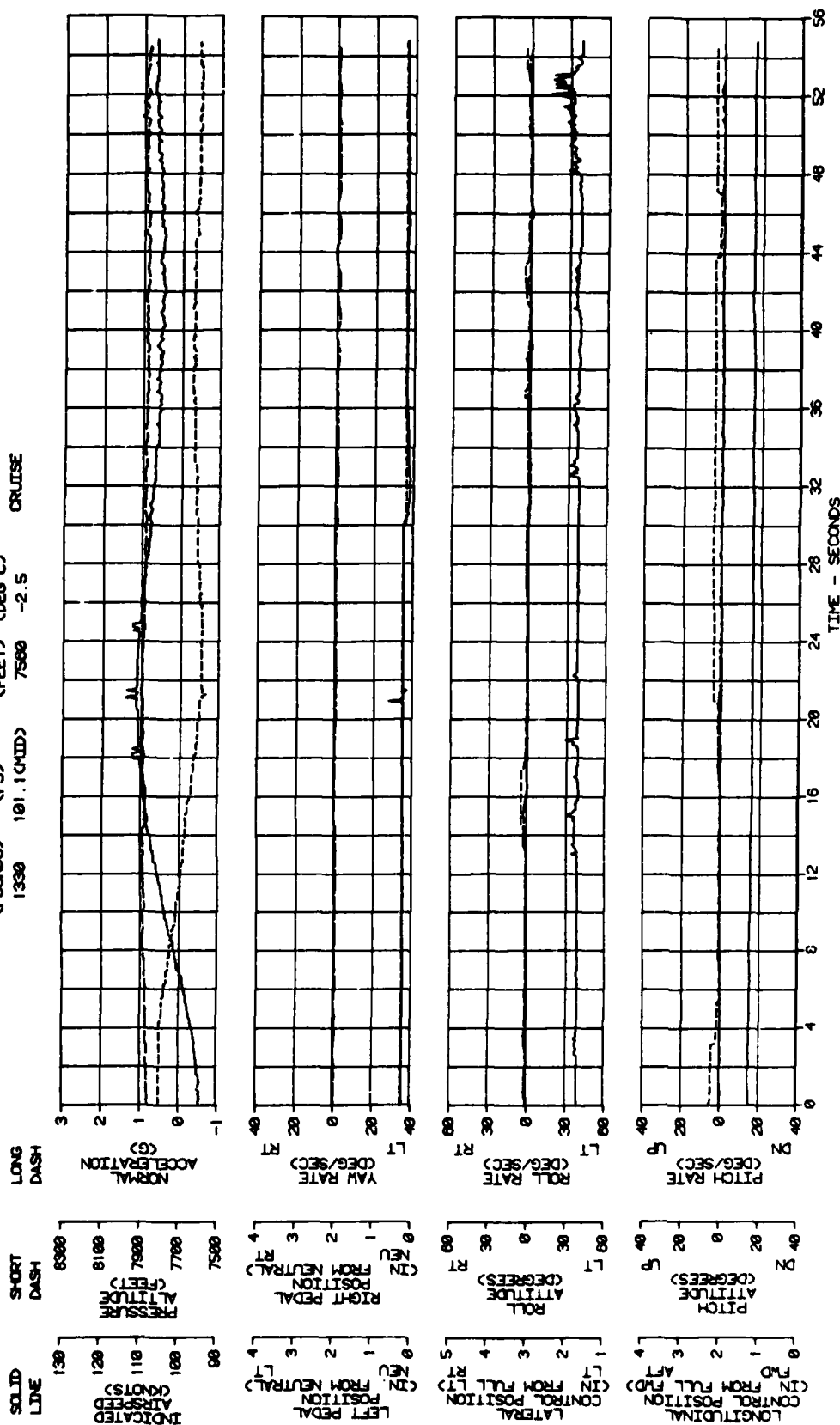


FIGURE 22
 LONGITUDINAL SHORT PERIOD RESPONSE
 LONG-EZ USA S/N 82-1241 (N1241)
 AIRCRAFT CONFIGURATION
 LONGITUDINAL DENSITY OAT
 GROSS WEIGHT CG LOCATION ALTITUDE (DEG C)
 (POUNDS) (FS) (FEET)
 1320 180.8(MID) 7520 -2.5 CRUISE

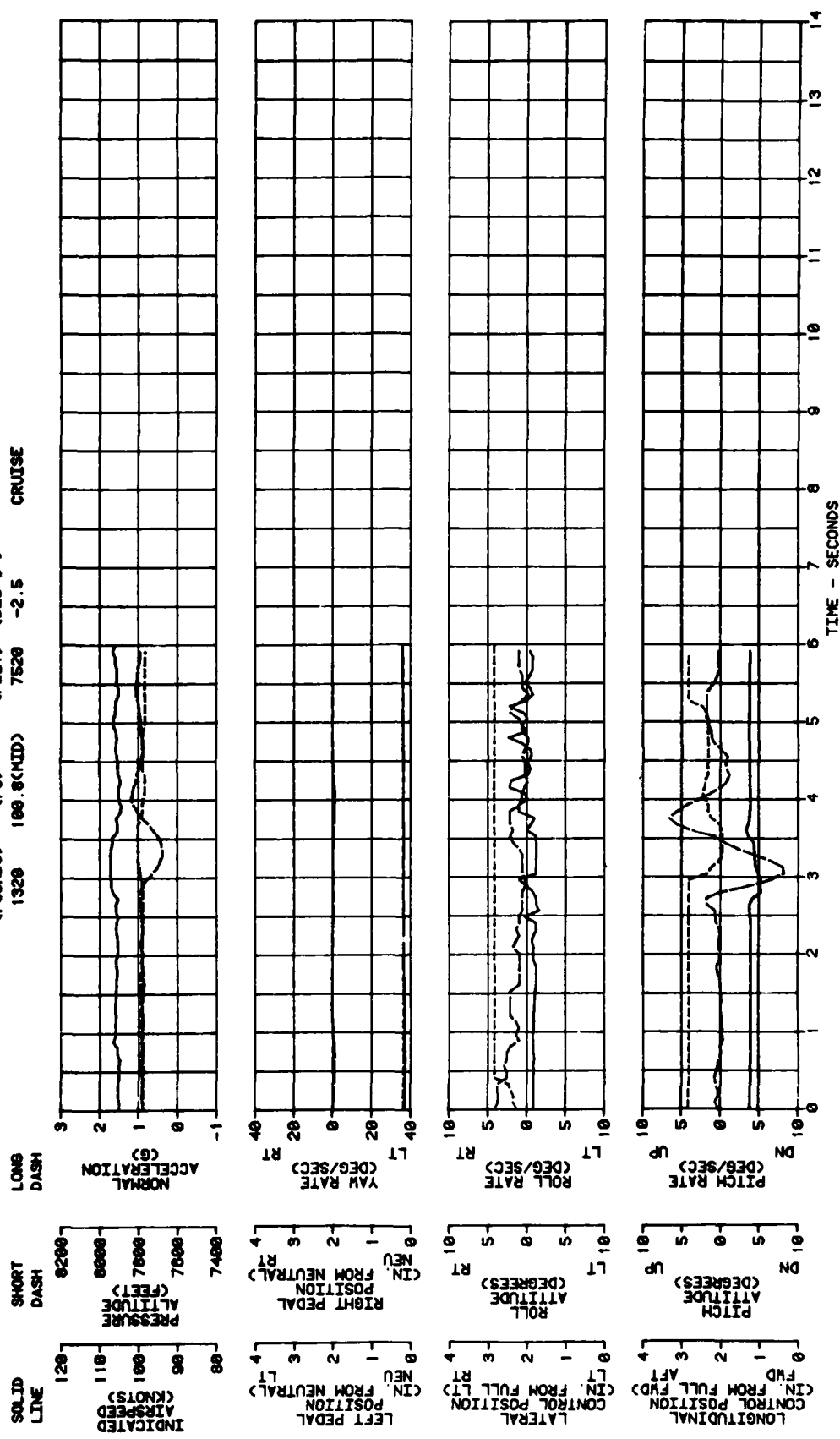


FIGURE 23
 LATERAL-DIRECTIONAL RESPONSE
 LONG-EZ USA S/N 82-1241 (N1241)
 GROSS WEIGHT (POUNDS) 13300
 LONGITUDINAL DENSITY (FS) 101.1 (MID)
 AIRCRAFT CONFIGURATION OAT
 CG LOCATION (FEET) 7400
 ALTITUDE (DEG C) -2.5
 CRUISE

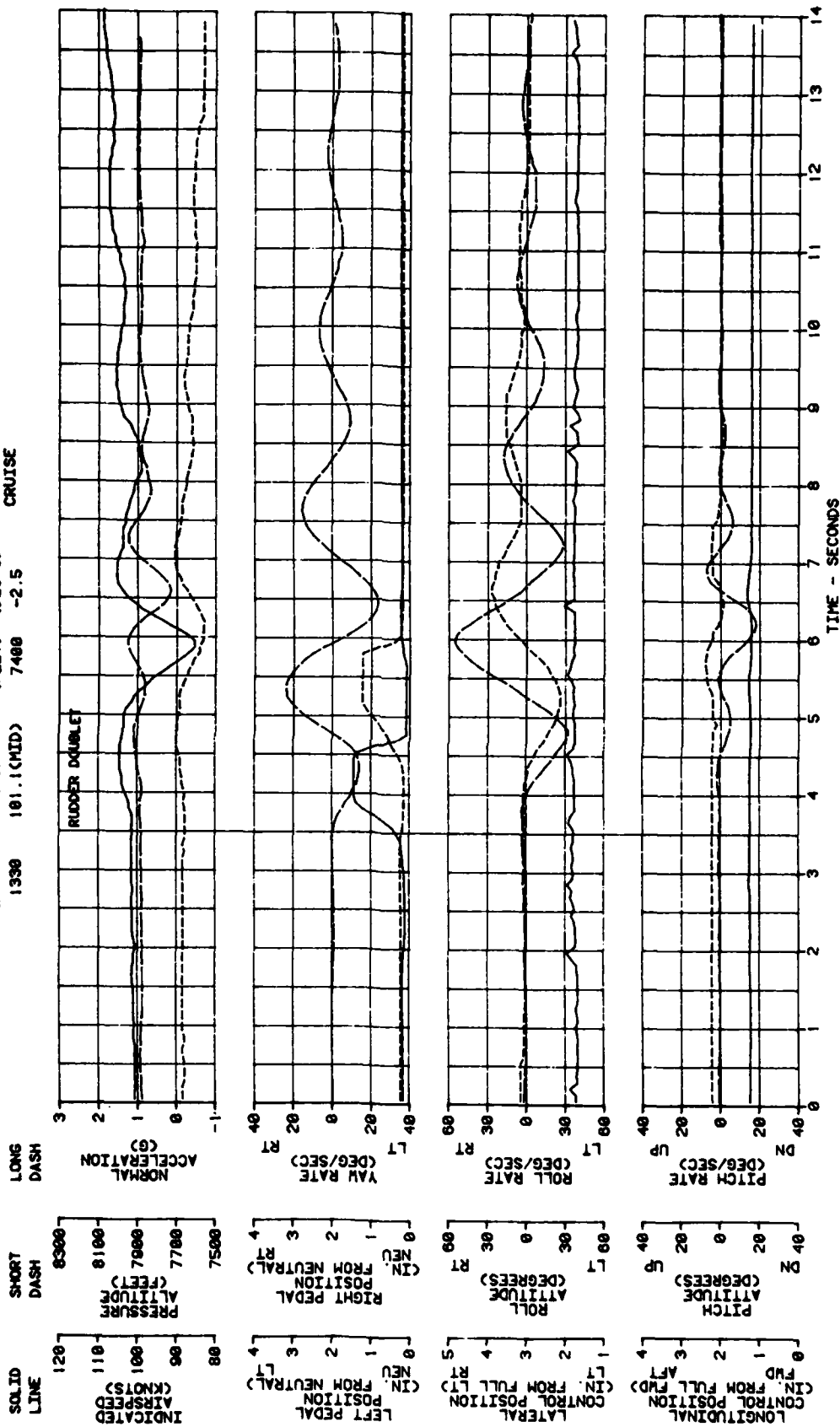


FIGURE 24
LATERAL-DIRECTIONAL RESPONSE
LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (POUNDS) 1330
LONGITUDINAL ALTITUDE (FEET) 4000
CLIMB 4.5
SIDESLIP ANGLE (DEG C) 17.0

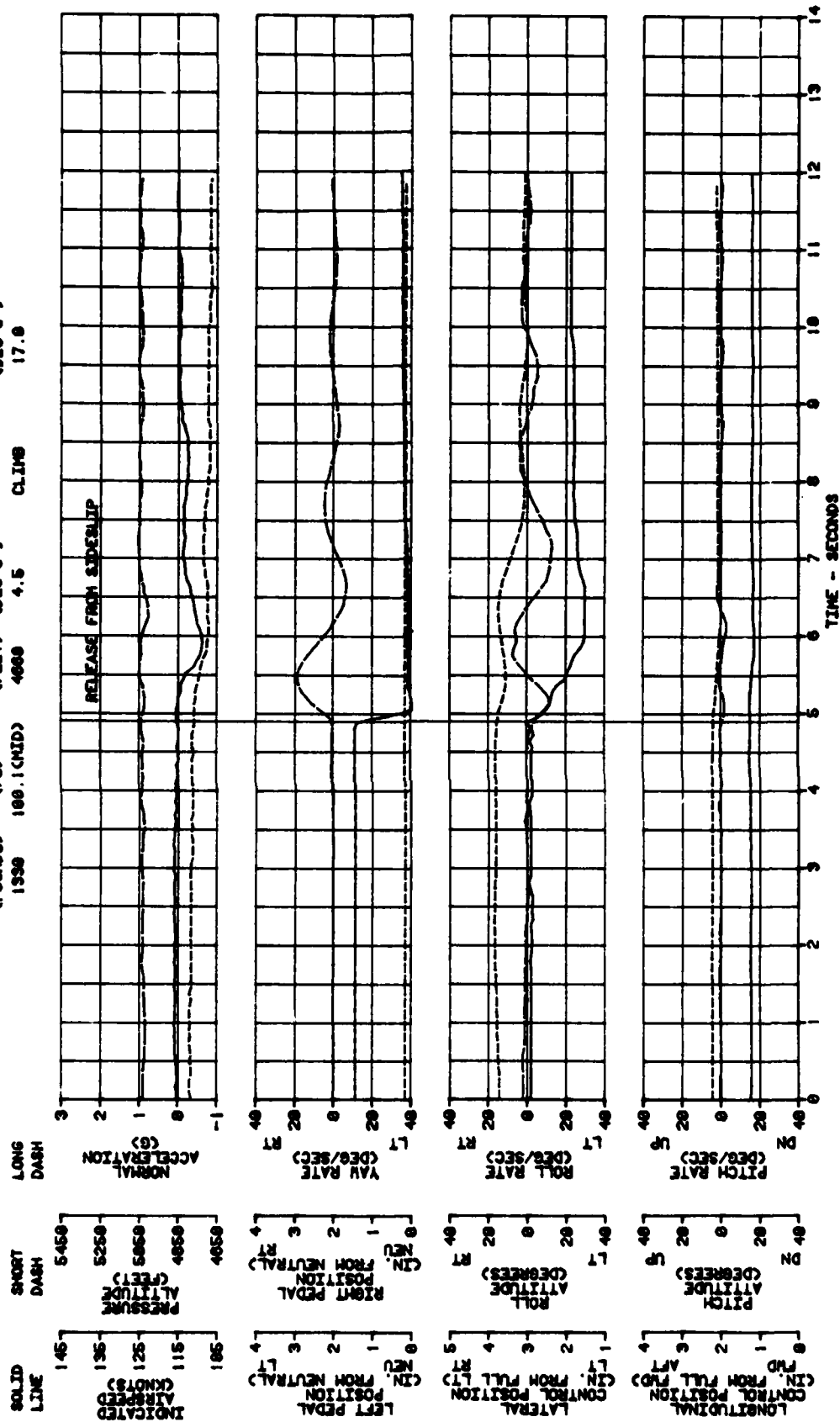


FIGURE 25
 LATERAL-DIRECTIONAL RESPONSE
 LONG-EZ USA S/N 82-1241 (N1241)
 LONGITUDINAL DENSITY DAT AIRCRAFT
 WEIGHT CS LOCATION ALTITUDE CONFIGURATION
 (POUNDS) (FEET) (DEG C) (DEG C)
 1300 100.1 (CHD) 4500 4.5 CLING 10.0
 SLIDELIP
 ANGLE
 (DEG C)

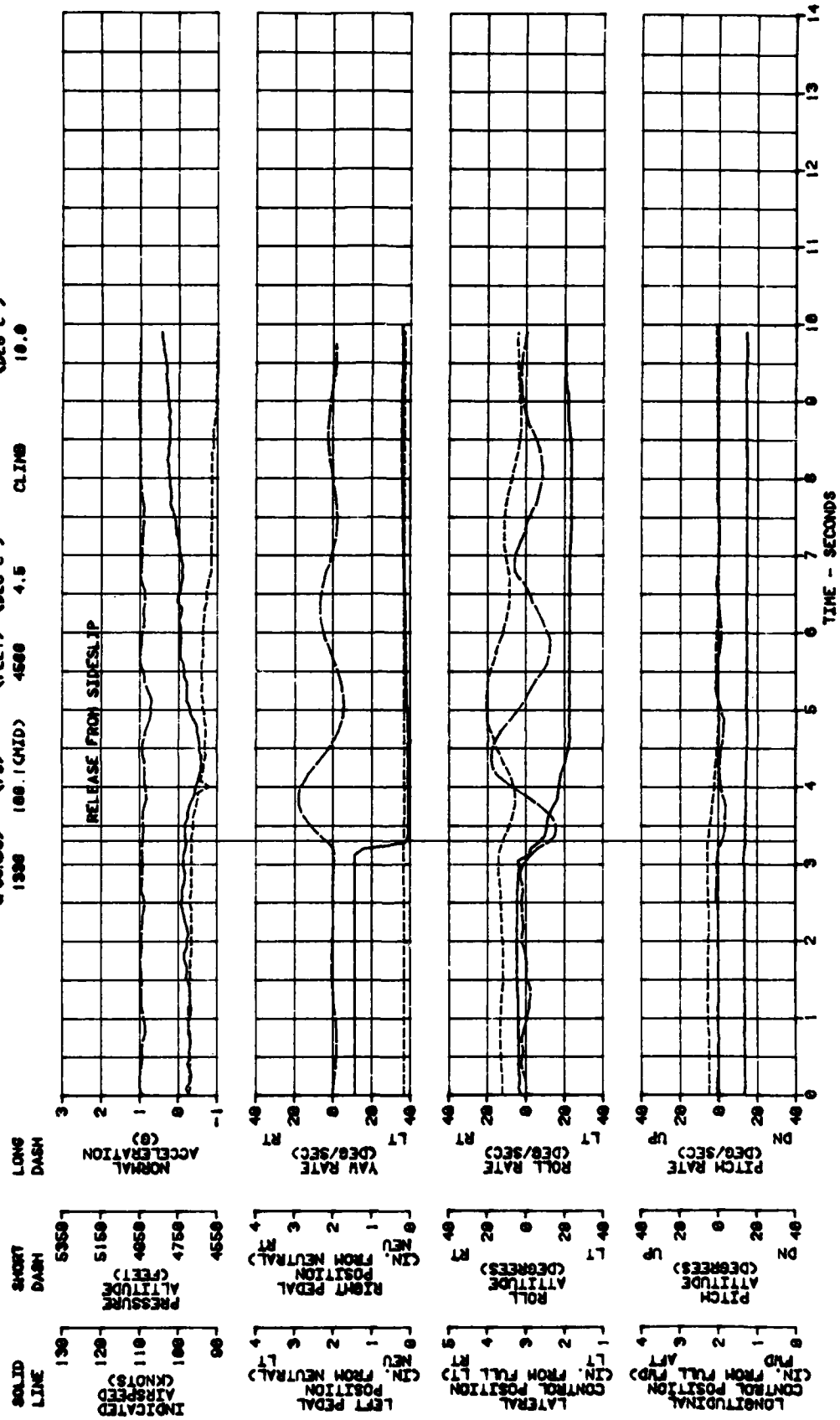


FIGURE 26
LATERAL-DIRECTIONAL RESPONSE

LONG-EZ USA S/N 82-1241 (N1241)
GROSS WEIGHT (LBS) 13000
LONGITUDINAL DENSITY (GPM) 160.1 (MID)
AIRCRAFT CONFIGURATION (DEG C) 3.5
SIDE SLIP ANGLE (DEG C) 14.0
LANDING 5000

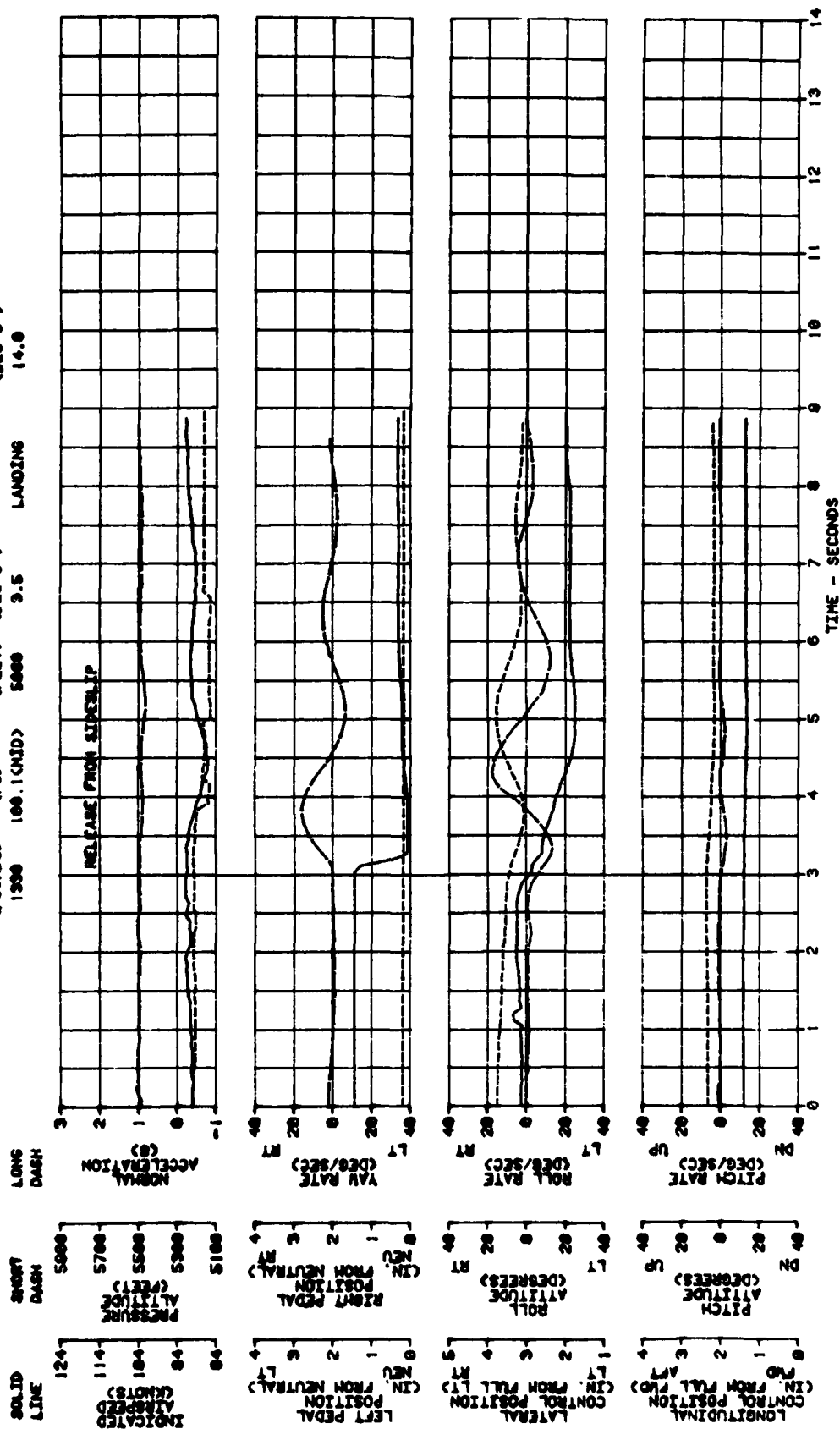


FIGURE 27
GUST RESPONSE
LONG-EZ USA S/N 82-1241 (N1241)
AIRCRAFT CONFIGURATION
LANDING

GROSS WEIGHT (POUNDS) 1360
LONGITUDINAL CG LOCATION (FSS) 101.0 (MID)
DENSITY ALTITUDE (FEET) 2620
INDICATED AIRSPEED (KNOTS) 80
OAT (DEG C) 12.5

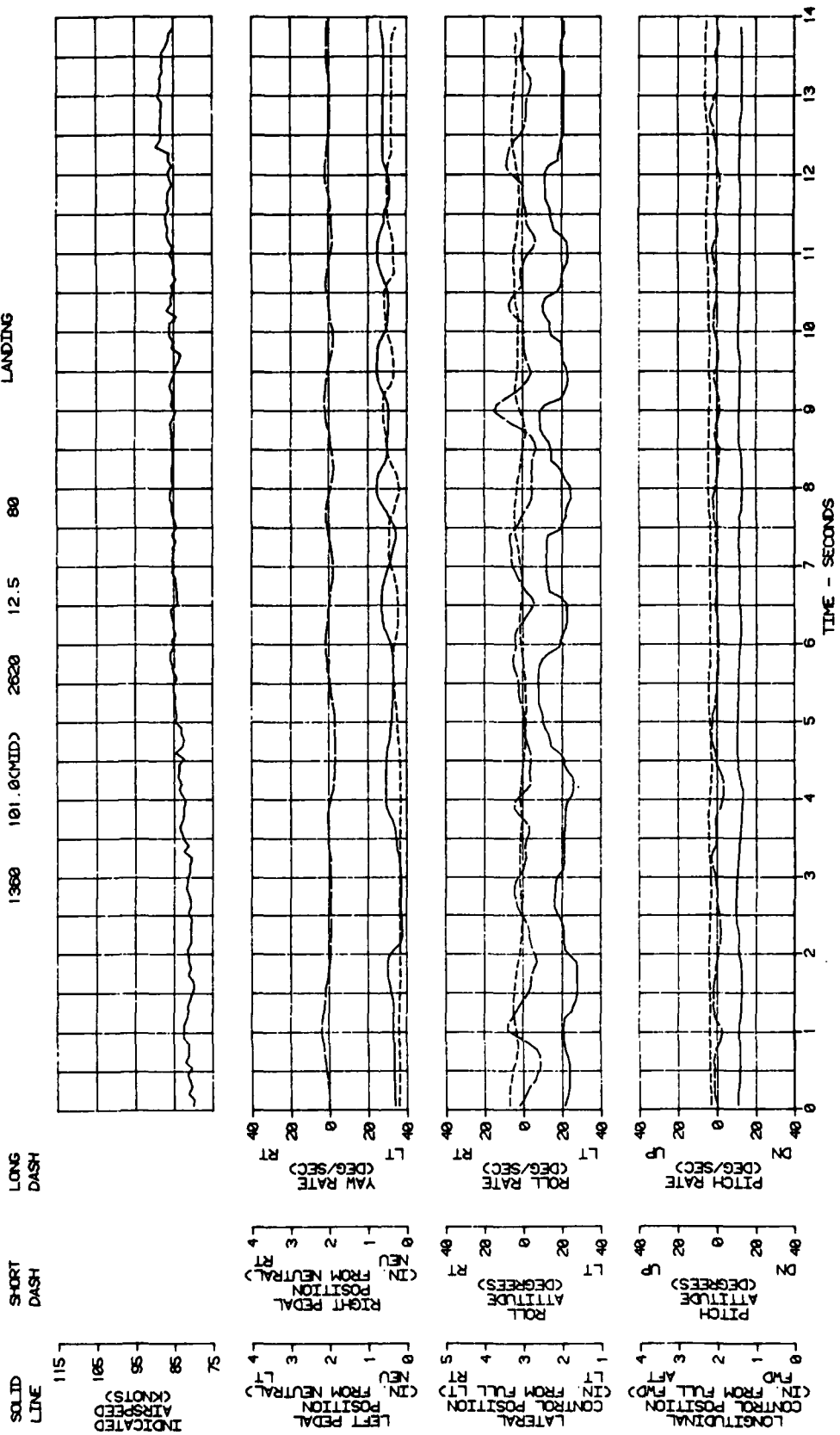


FIGURE 28 ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1241 (N1241)
AIRCRAFT CONFIGURATION
LONGITUDINAL DENSITY OAT
GROSS WEIGHT (POUNDS) 1370
CG LOCATION (FEET) 7400
ALTITUDE (DEG C) -1.0
CRUISE

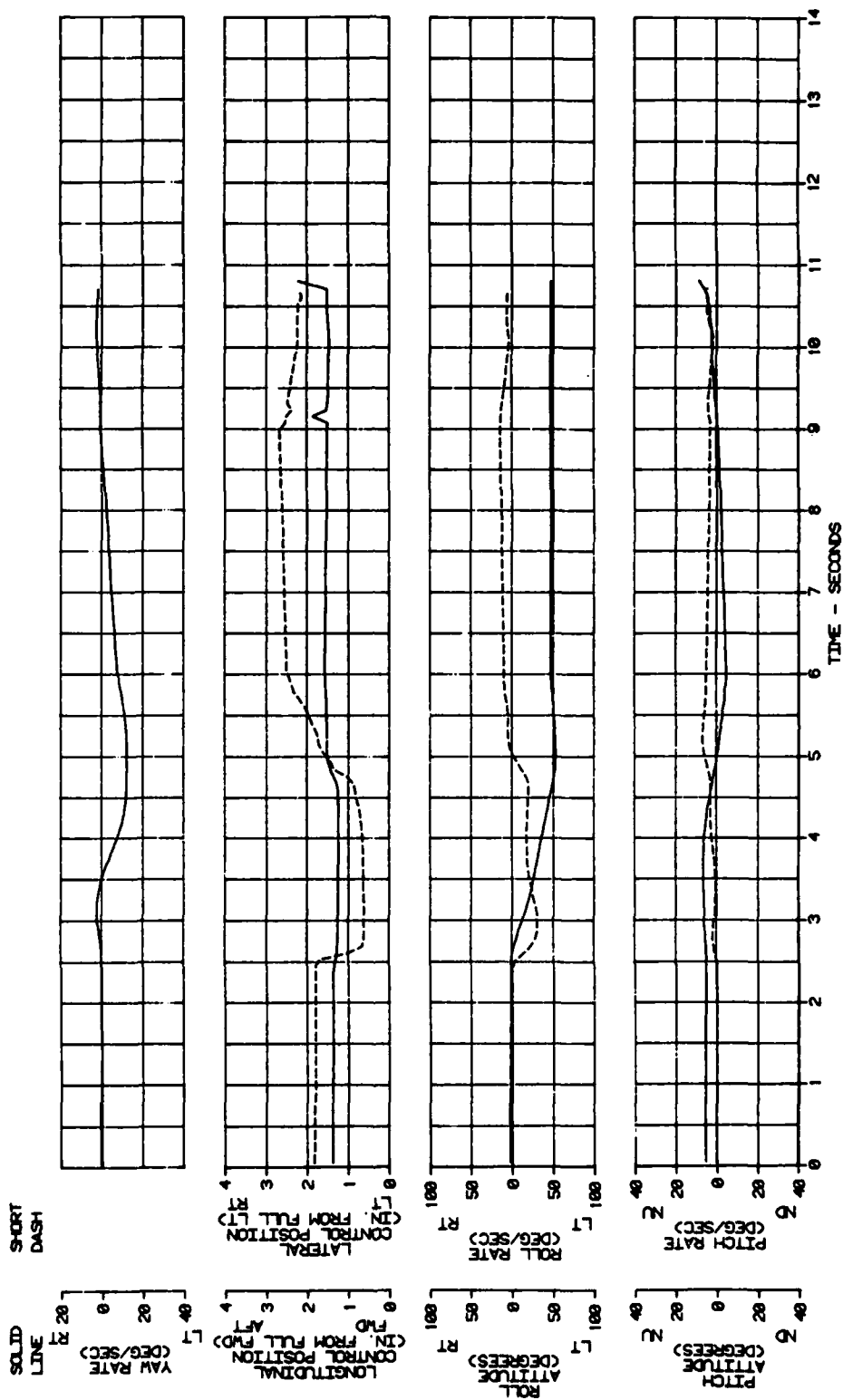


FIGURE 29
 ROLL CONTROL EFFECTIVENESS
 LONG-EZ USA S/N 82-1241 (N1241)
 LONGITUDINAL DENSITY QAT AIRCRAFT
 GROSS WEIGHT (POUNDS) 1370 100.3(MID) 7380 -1.0 CRUISE
 CG LOCATION (FEET) (DEG C)

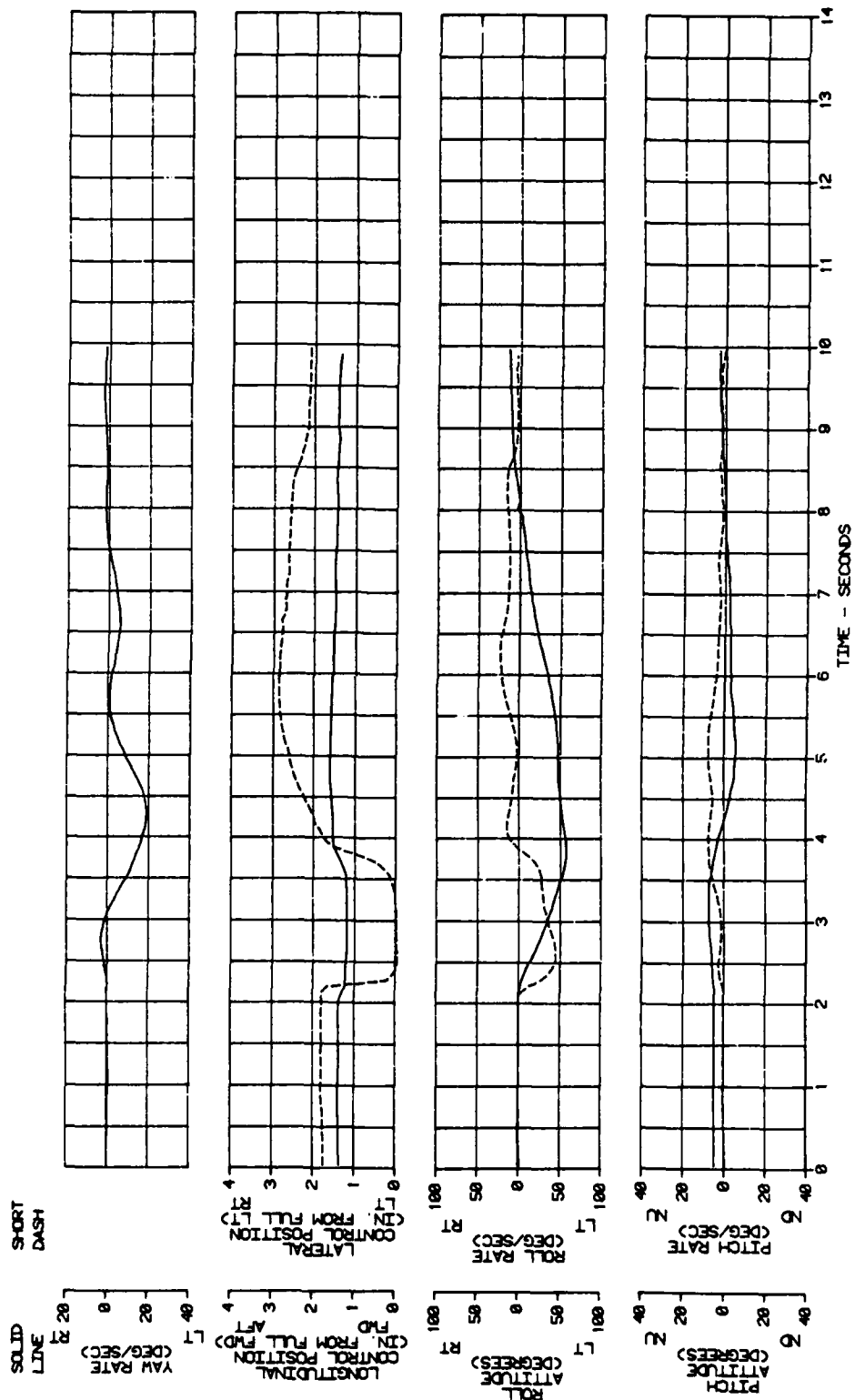


FIGURE 30
 ROLL CONTROL EFFECTIVENESS
 LONG-EZ USA S/N 82-1241 (N1241)
 AIRCRAFT
 LONGITUDINAL DENSITY QAT
 WEIGHT CG LOCATION ALTITUDE CONFIGURATION
 (POUNDS) (FEET) (DEG C)
 1378 100.30(MID) 7340 -0.5 CRUISE

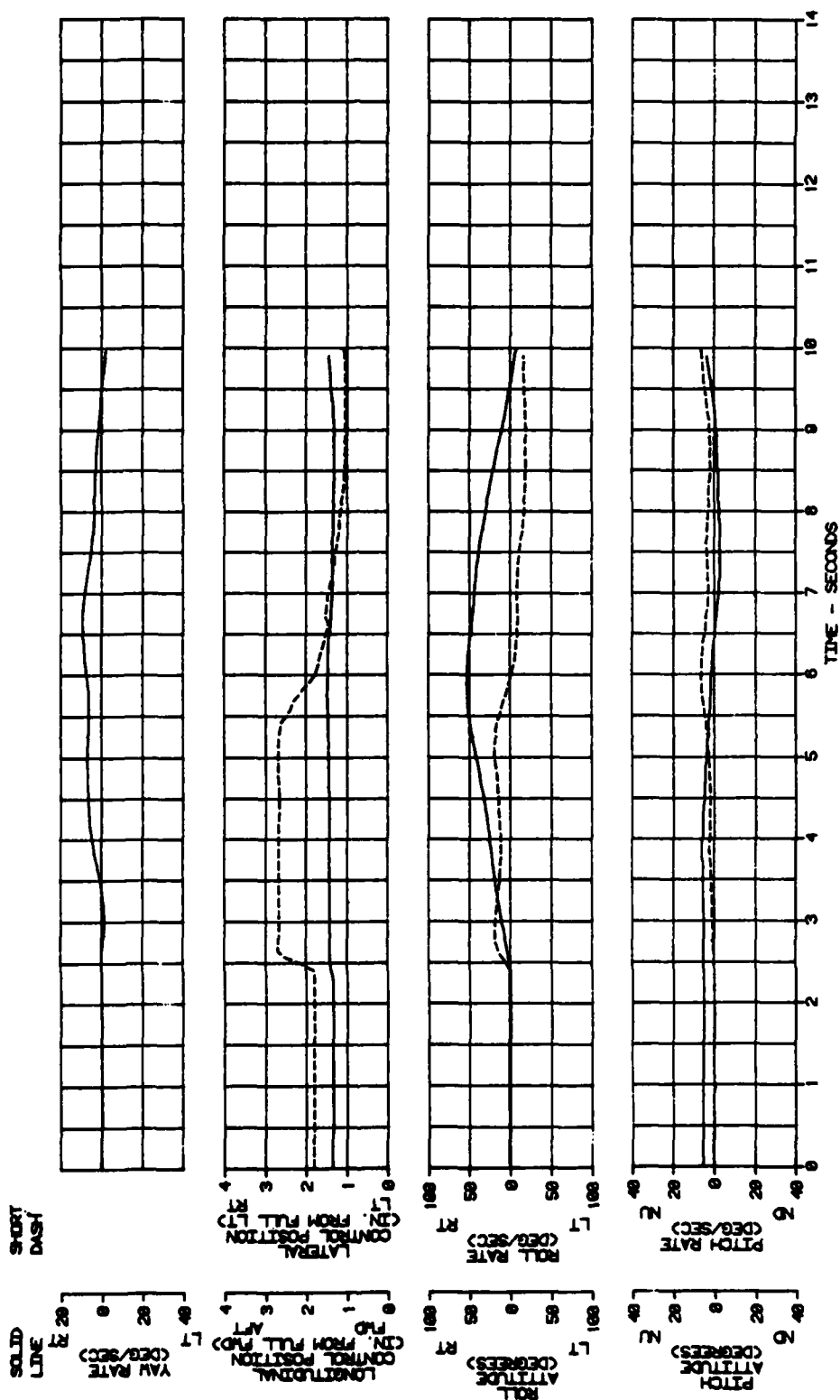


FIGURE 31
ROLL CONTROL EFFECTIVENESS

LONG-EZ USA S/N 82-1241 (N1241)
LONGITUDINAL DENSITY OAT AIRCRAFT
WEIGHT (POUNDS) 1370 100.3 (HDD) 7420 -1.0 CRUISE
CG LOCATION ALTITUDE (FEET) (DEG C)

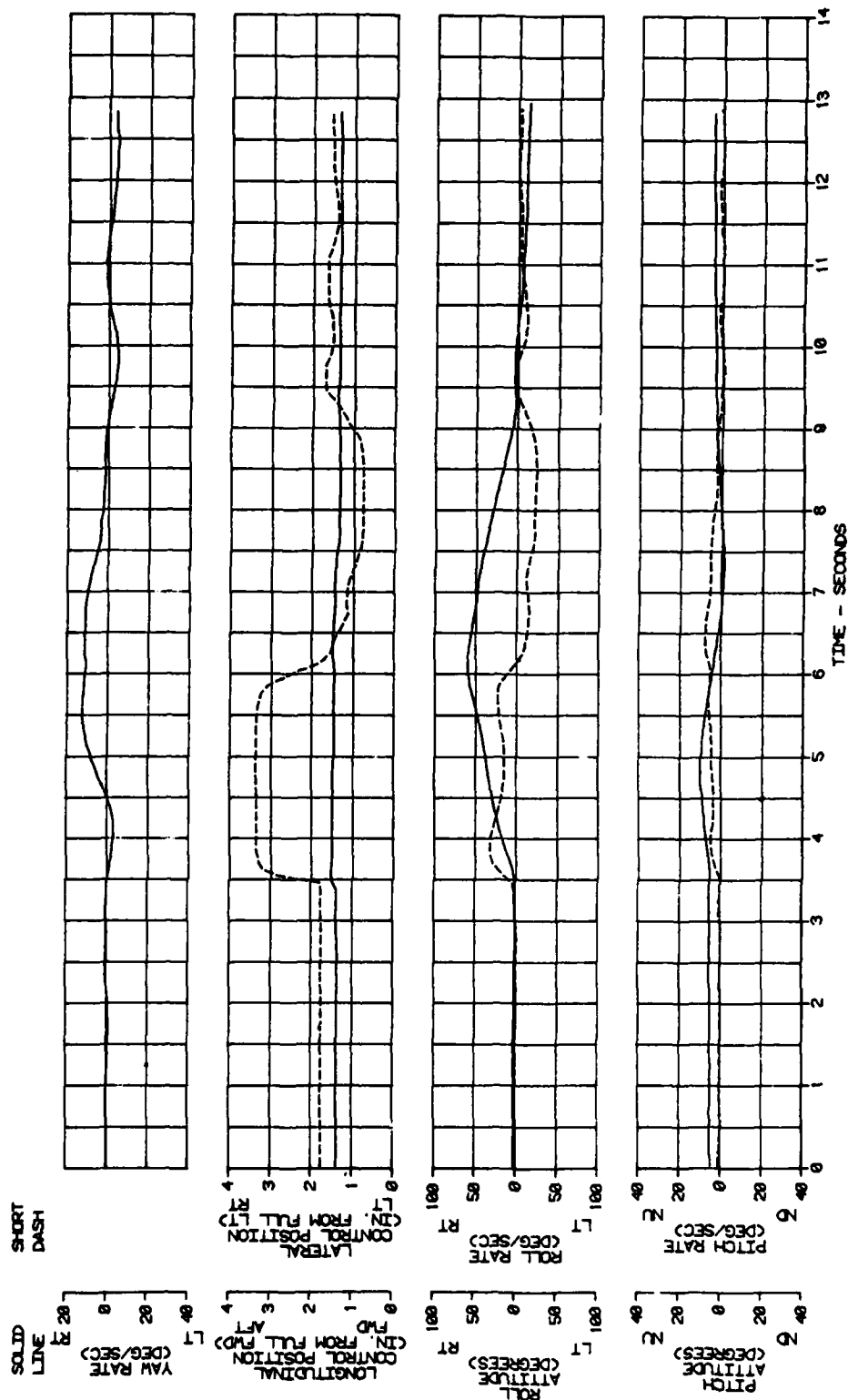


FIGURE 32
 TAKEOFF PERFORMANCE
 LONG-EZ USA S/N 82-1241 (N1241)
 GROSS WEIGHT 1335 LONGITUDINAL PRESSURE QAT
 CG LOCATION 100.9 (MD) ALTITUDE (FEET) AIRCRAFT
 (FS) 2200 15.0 CONFIGURATION
 TAKEOFF

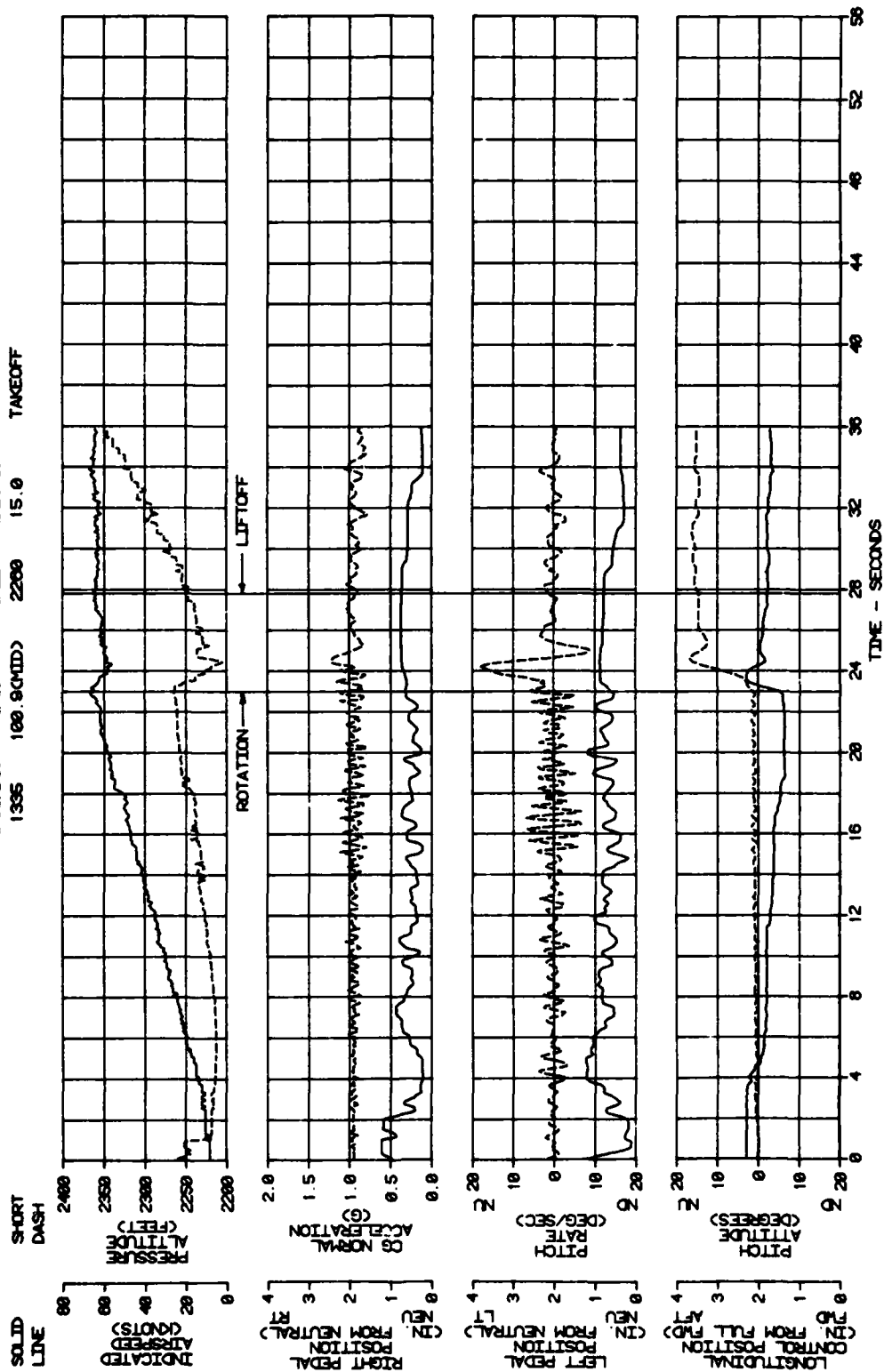


FIGURE 33
LANDING PERFORMANCE
LONG-EZ USA S/N 82-1241 (N1241)
LONGITUDINAL PRESSURE OAT
WEIGHT CG LOCATION ALTITUDE
(POUNDS) (FS) (DEG C) CONFIGURATION
1945 100.90 (HD) 2280 13.0 LANDING

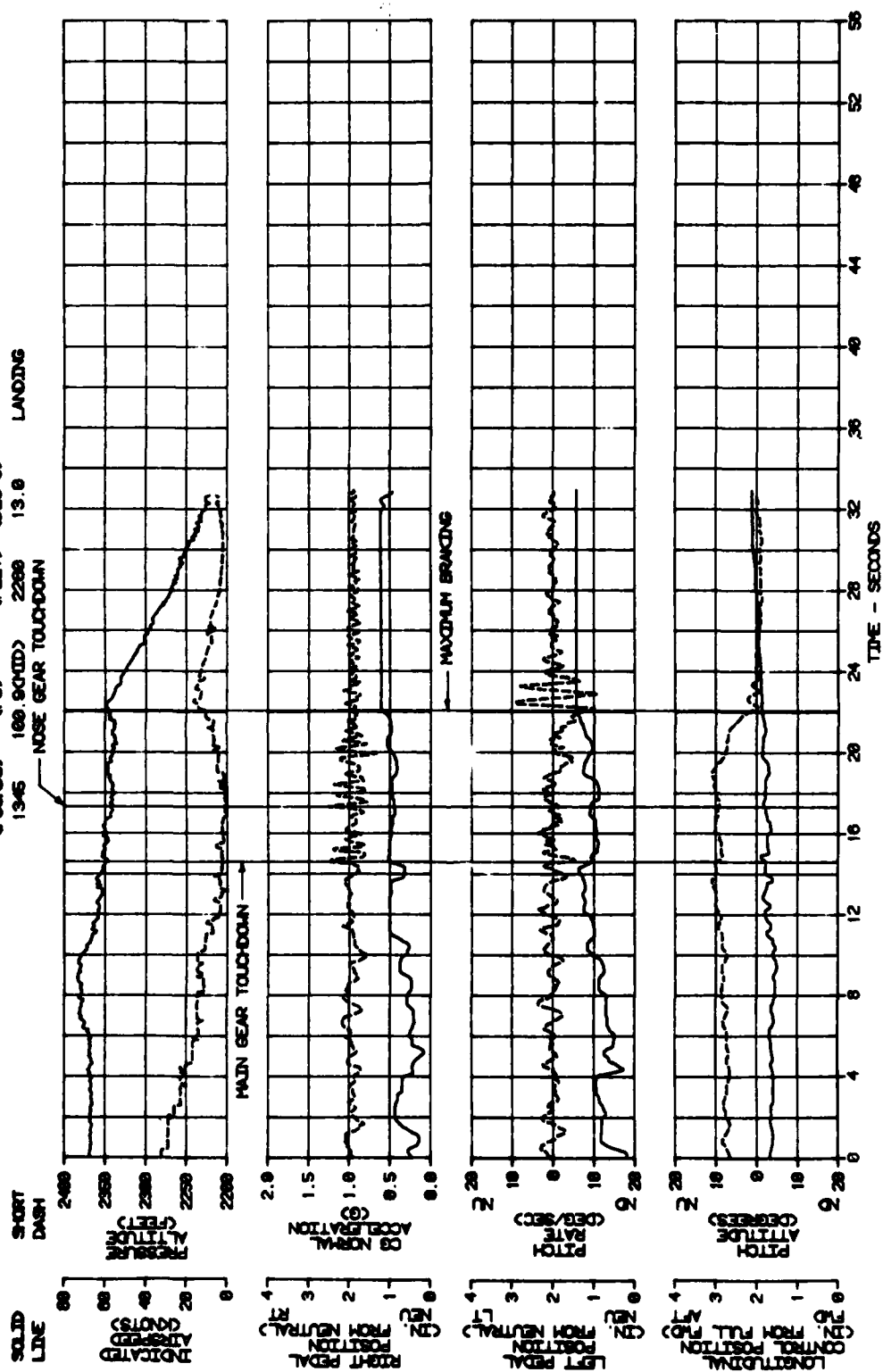


FIGURE 34
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIP LONGITUDINAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (F5)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
○	1325	101.2(MID)	5980	1.0	CLIMB
△	1315	101.1(MID)	5400	2.0	LANDING
□	1305	101.1(MID)	4980	2.5	CRUISE(DIVE)
★	1296	101.1(MID)	4480	4.0	CRUISE(DESCENT)
◻	1295	101.0(MID)	4700	3.5	CRUISE(LEVEL)

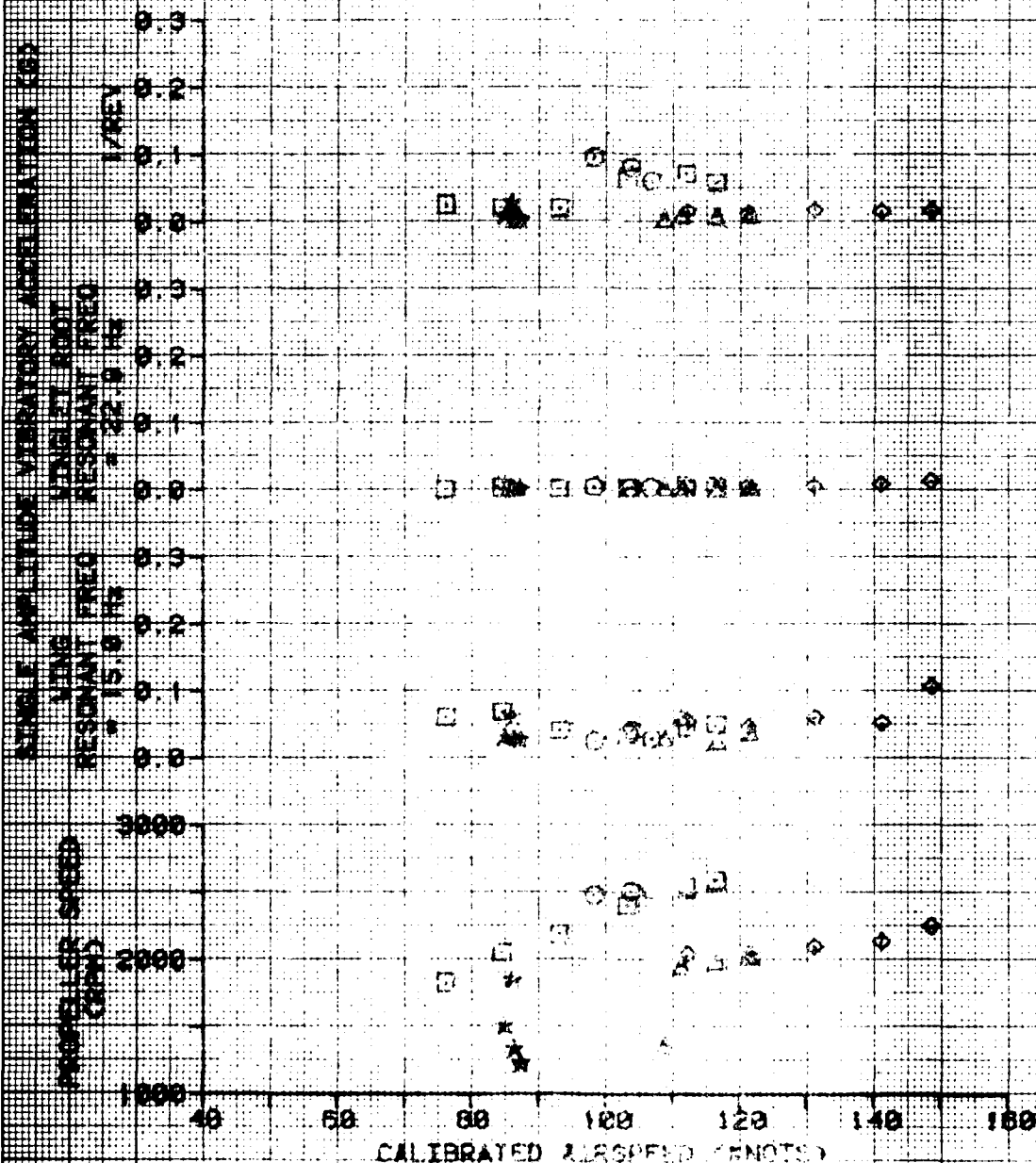
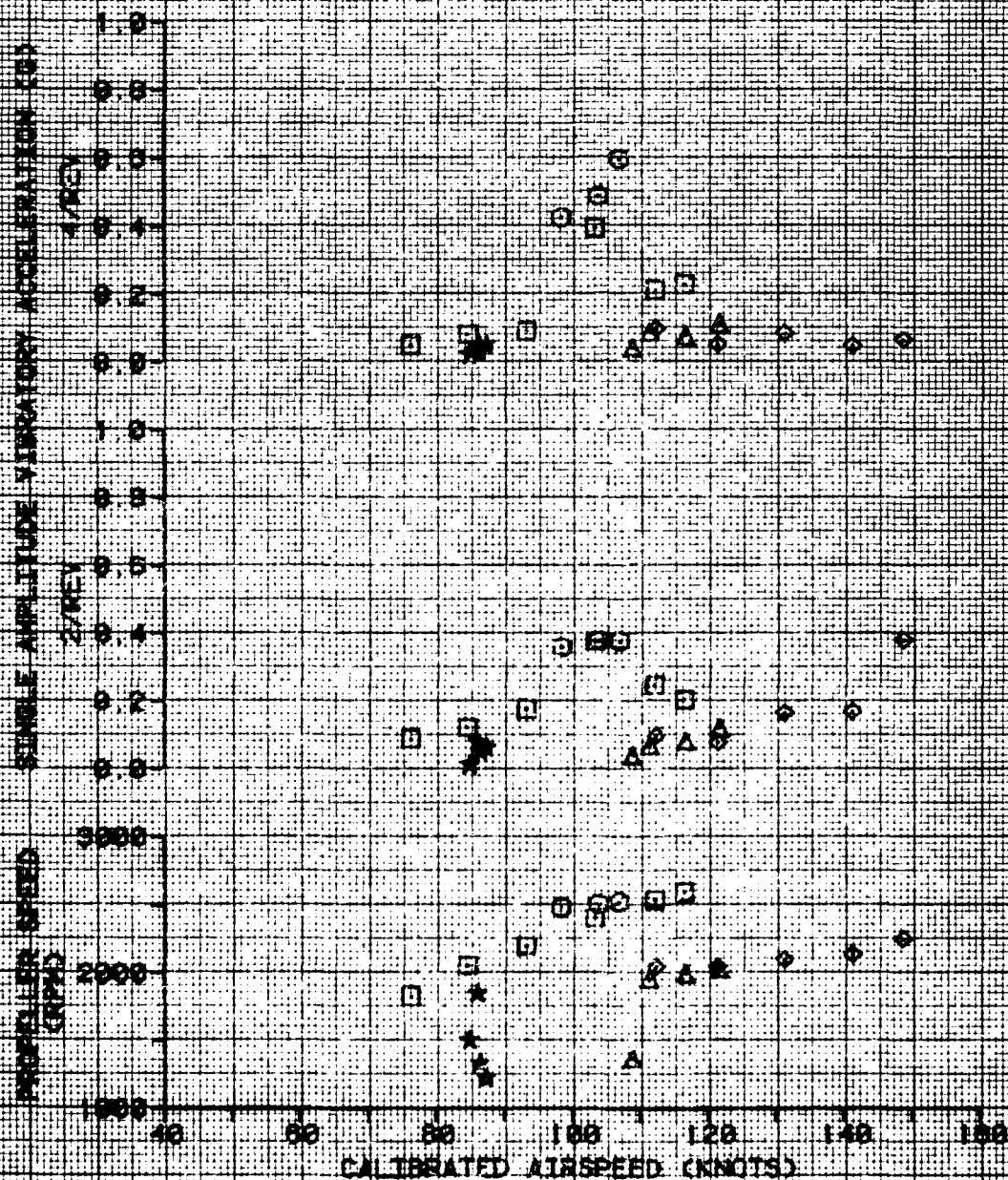


FIGURE 35
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LONGITUDINAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (F5)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
○	1325	101.2(MID)	5000	1.0	FLIGHT
△	1315	101.1(MID)	5400	2.0	LANDING
□	1305	101.1(MID)	4900	2.5	CRUISE(DESC)
★	1295	101.1(MID)	4400	4.0	CRUISE(DESCENT)
□	1295	101.0(MID)	4700	5.5	CRUISE(LEVEL)



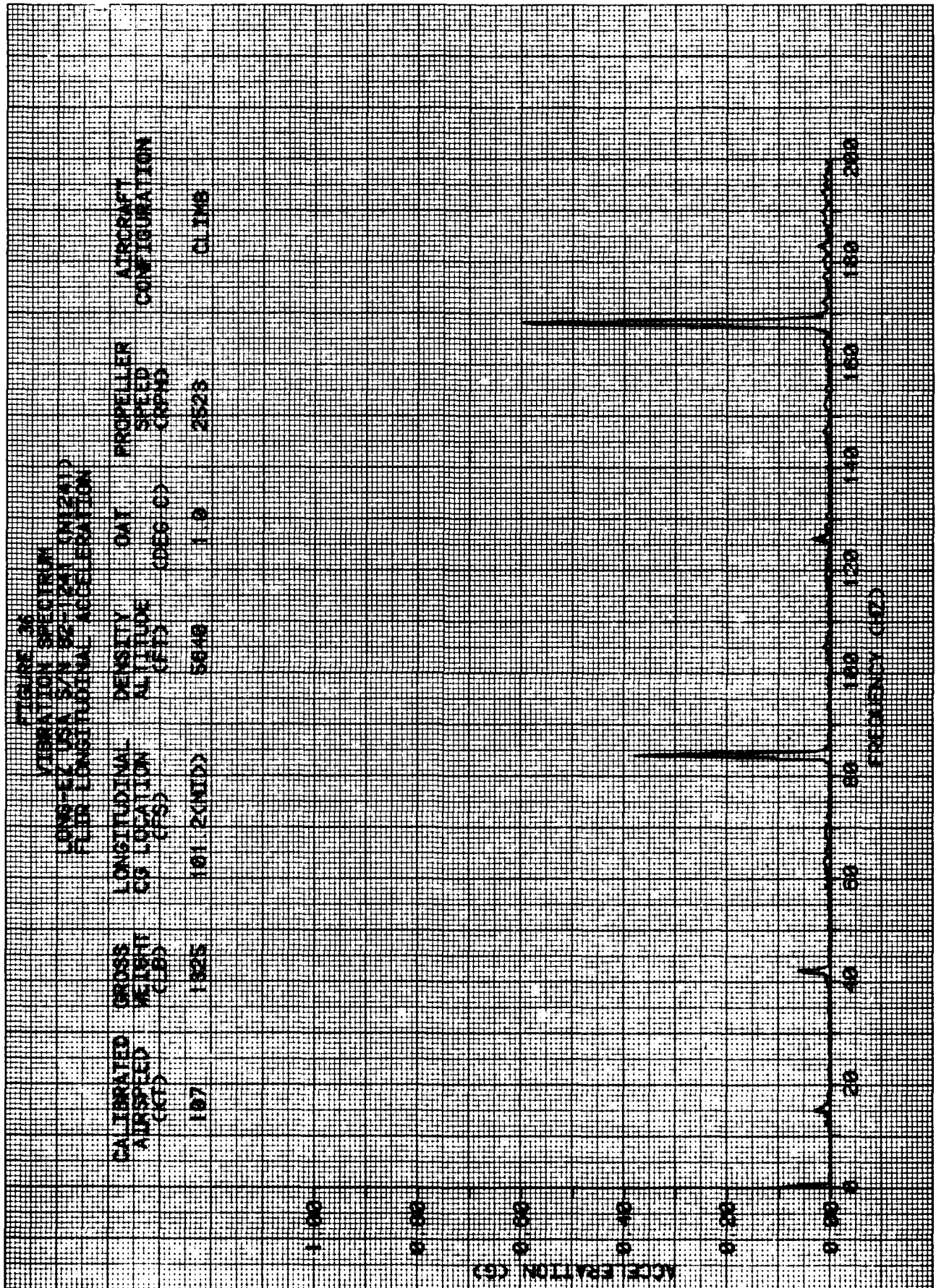
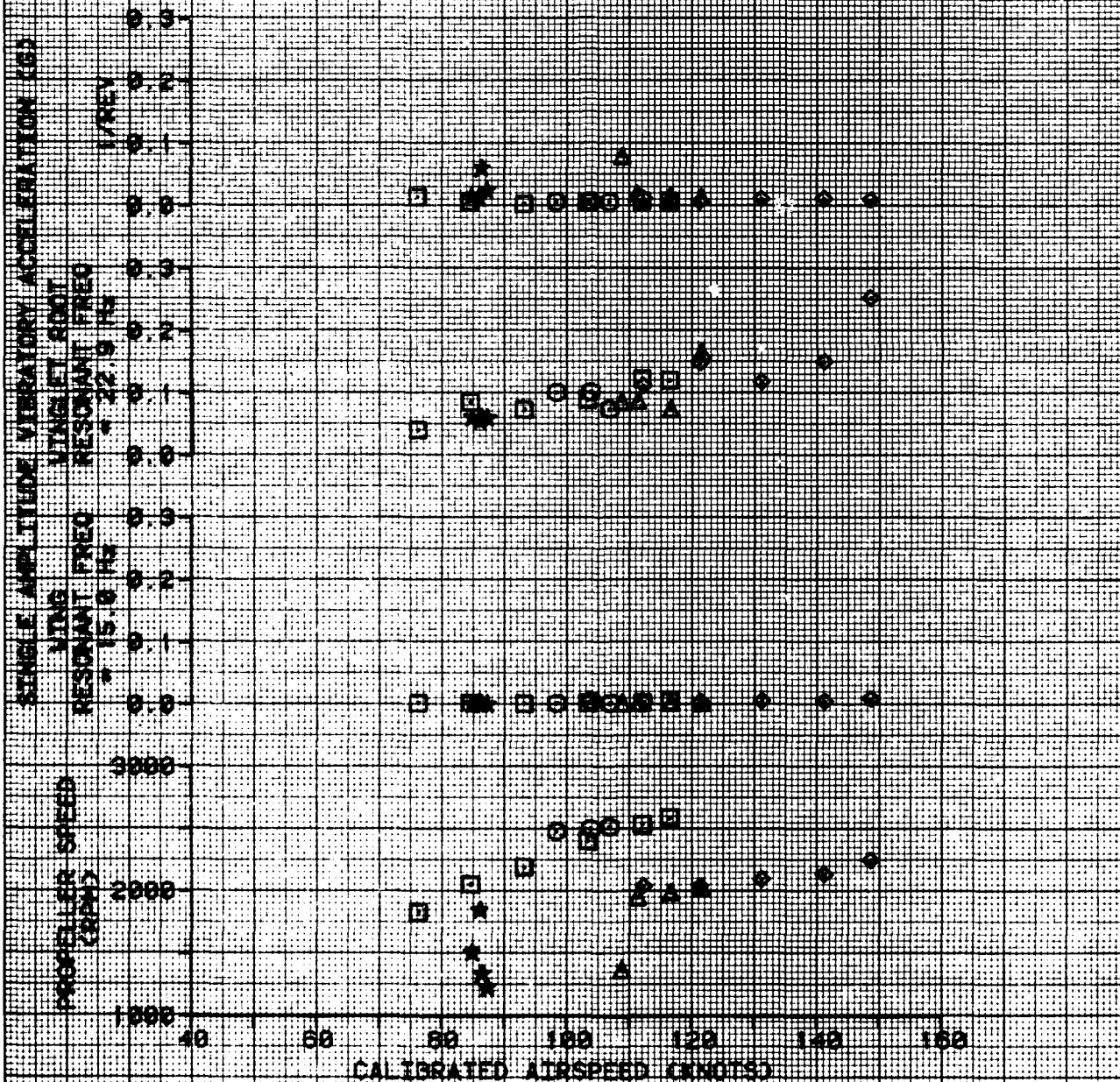


FIGURE 37
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LATERAL ACCELERATION

SYM	AVG GROSS WEIGHT (POUNDS)	AVG LONGITUDINAL CG LOCATION (FSS)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AIRCRAFT CONFIGURATION
○	1325	101.2 (MID)	5000	1.0	CLIMB
△	1315	101.1 (MID)	5400	2.0	LANDING
●	1305	101.1 (MID)	4900	2.5	CRUISE (CLIMB)
★	1295	101.1 (MID)	4400	4.0	CRUISE (DESCENT)
□	1295	101.0 (MID)	4700	3.5	CRUISE (LEVEL)



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PRELIMINARY AIRWORTHINESS EVALUATION OF THE RUTAN
AIRCRAFT FACTORY (RAF). (U) ARMY AVIATION ENGINEERING
FLIGHT ACTIVITY EDWARDS AFB CA D L UNDERWOOD ET AL.

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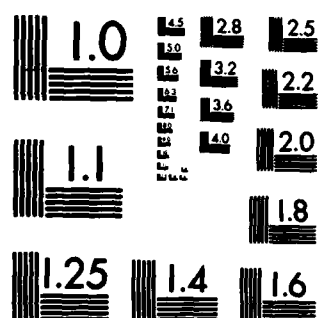
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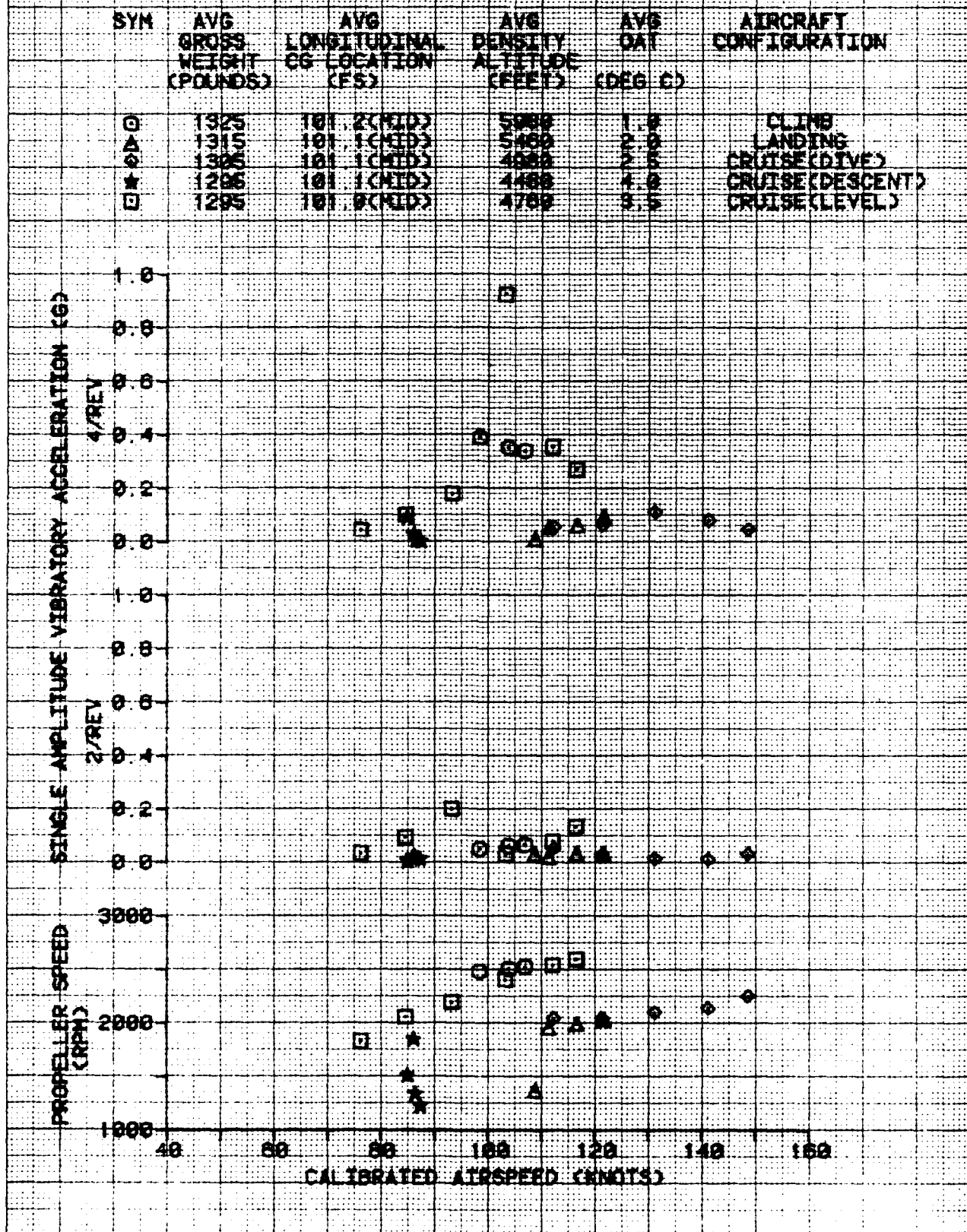
NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FIGURE 38
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR LATERAL ACCELERATION



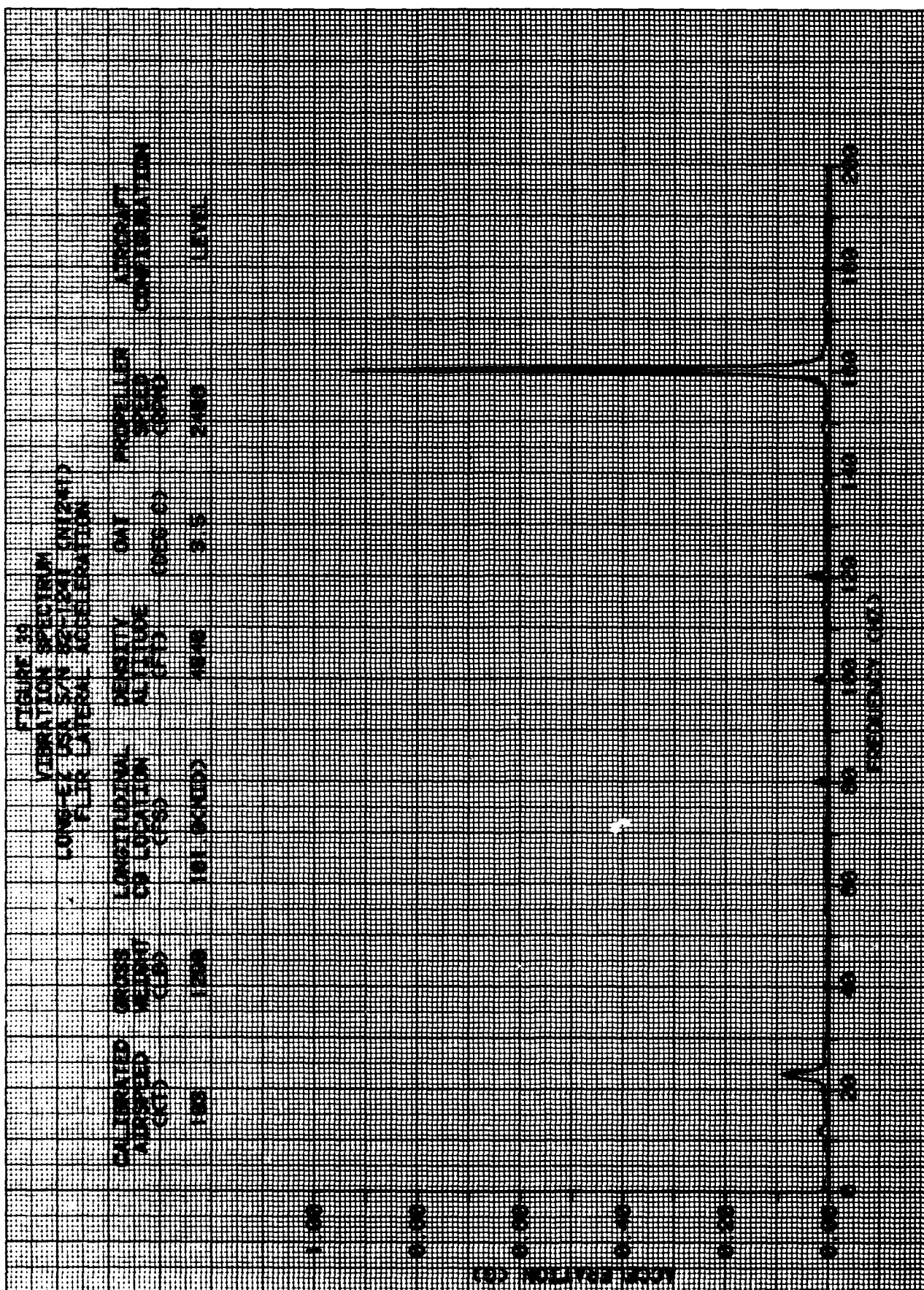


FIGURE 40
VIBRATION CHARACTERISTICS
LONG-EZ USA S/N 82-1241 (N1241)
FLIR VERTICAL ACCELERATION

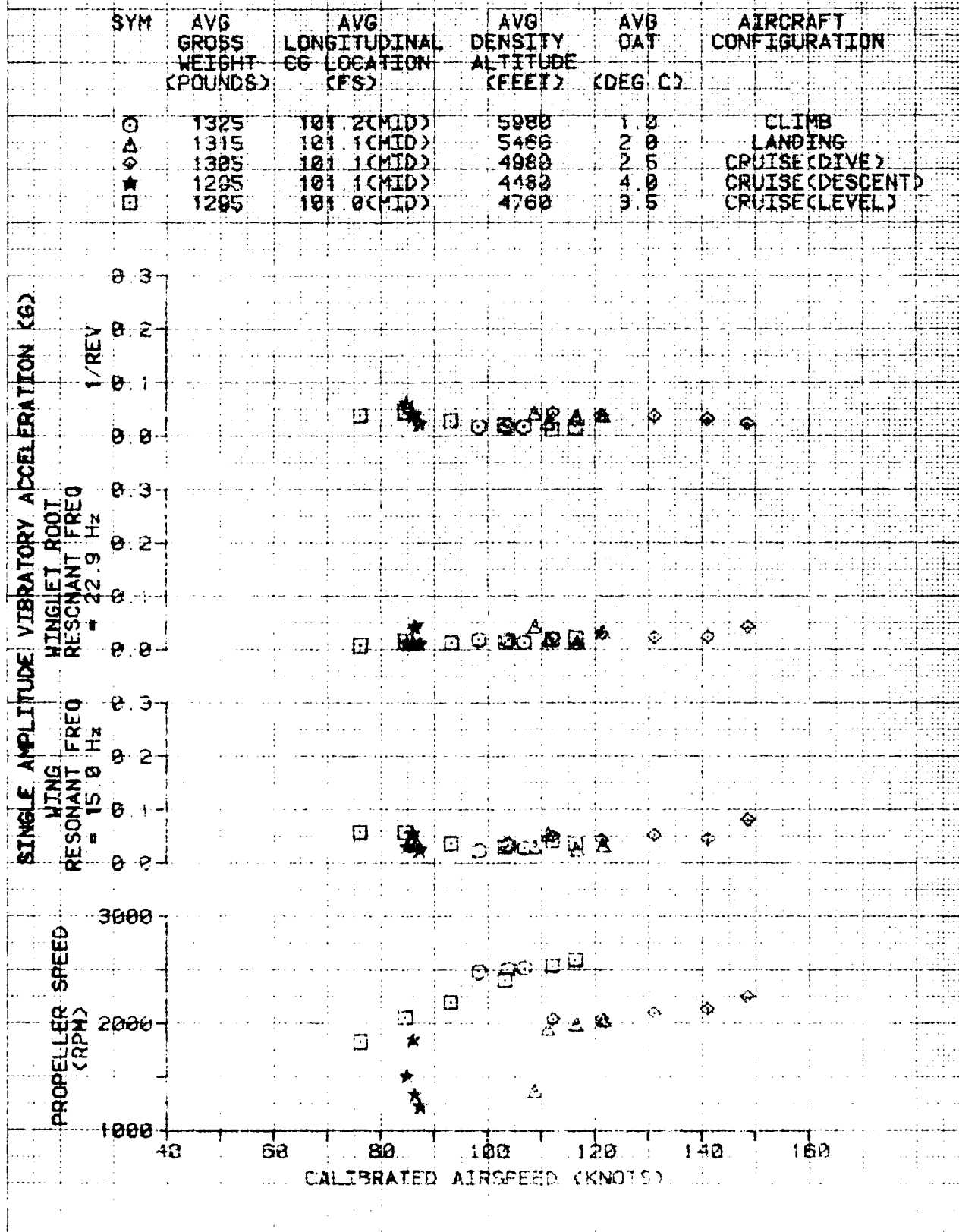


FIGURE A1
VIBRATION CHARACTERISTICS
LONG-EX USA S/N 82-1241 (N1241)
FLIER VERTICAL ACCELERATION

SYN	AVS GROSS WEIGHT (POUNDS)	AVS LONGITUDINAL CG LOCATION (FSS)	AVS DENSITY ALTITUDE (FEET)	AVS QAT (DEG C)	AIRCRAFT CONFIGURATION
0	1325	181.20(NID)	5000	1.0	CLIMB
1	1315	181.10(NID)	5400	2.0	LANDING
2	1305	181.10(NID)	4000	2.0	CRUISE (DIVE)
3	1295	181.10(NID)	4400	4.0	CRUISE (DESCENT)
4	1285	181.00(NID)	4700	9.5	CRUISE (LEVEL)

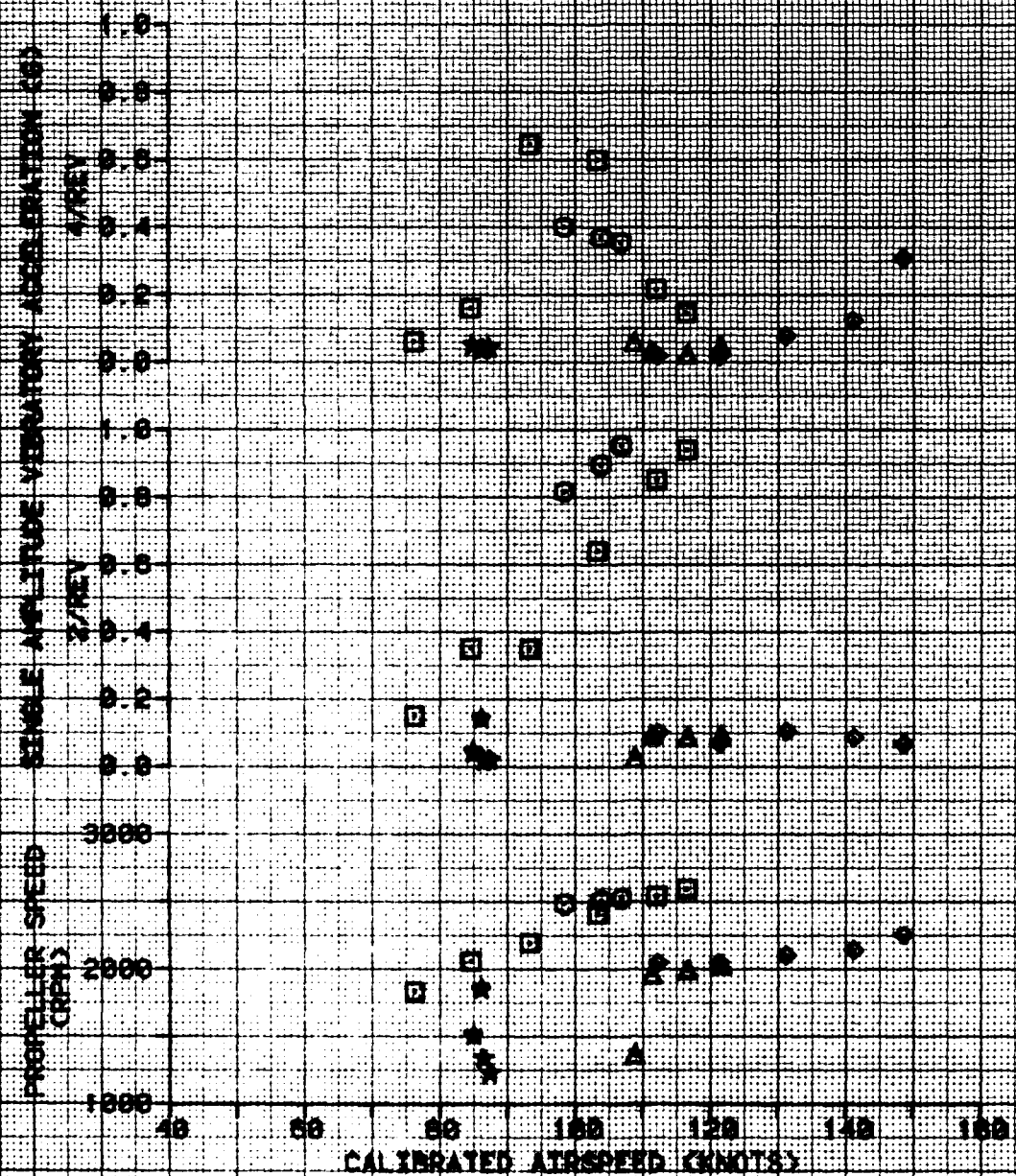


FIGURE 42
VIBRATION SPECTRUM
LONG-EZ USA S/N 82-1241 (M1241)
FLIR VERTICAL ACCELERATION

CALIBRATED AIRSPEED (KT)	GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FSD)	DENSITY ALTITUDE (FT)	OAT (DEG C)	PROPELLER SPEED (RPM)	AIRCRAFT CONFIGURATION
107	1325	101.2 (MID)	5640	1.0	2523	CLIMB

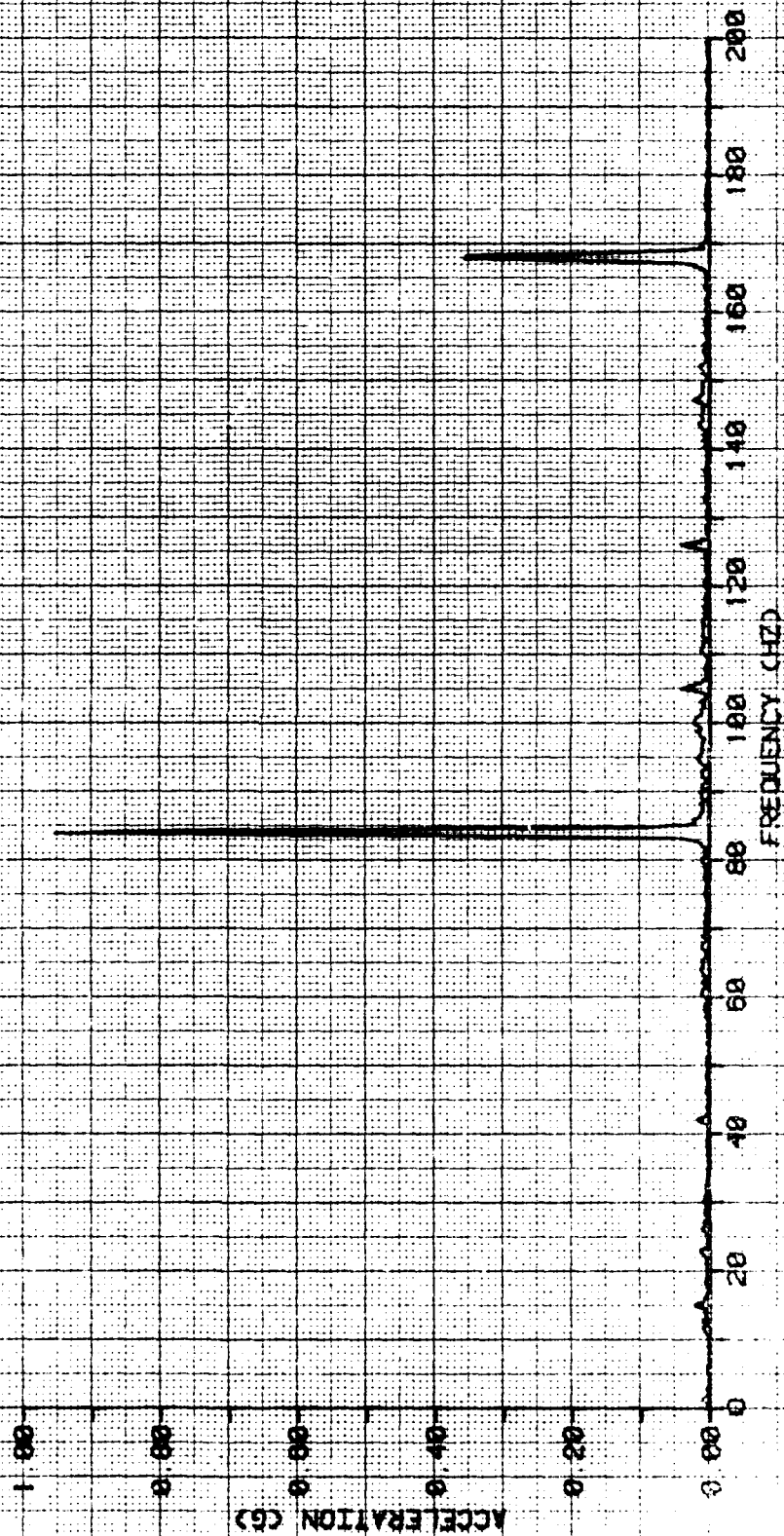
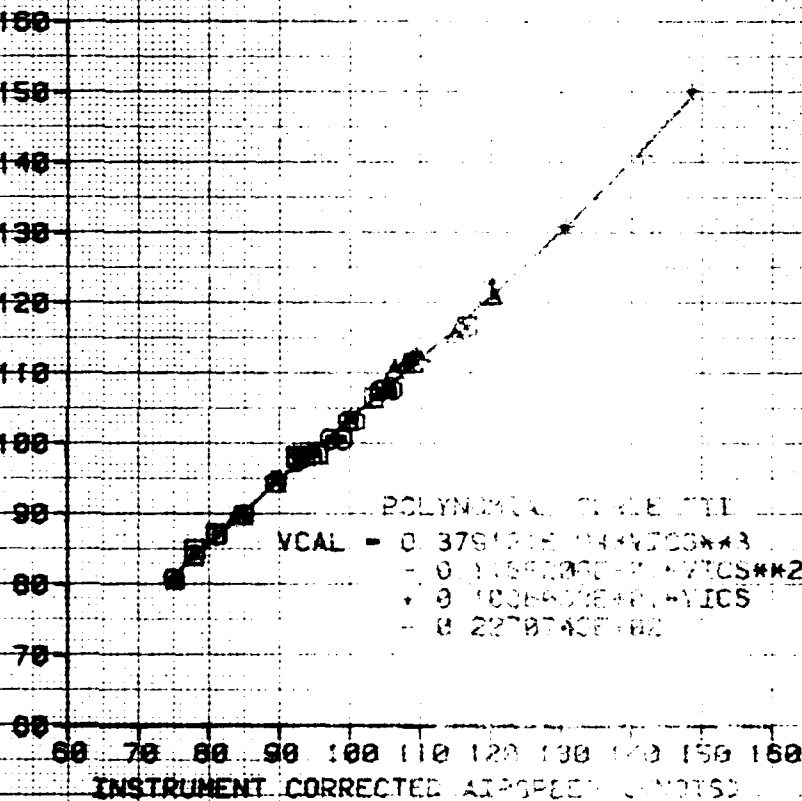


FIGURE 43
AIRSPEED CALIBRATION
LONG-EZ USA S/N 82-1241 (CN1241)
SHIP SYSTEM POSITION ERROR

SYM	AVG GROSS WEIGHT (LB)	AVG LONG LG LOCATION (FSS)	AVG DENSITY ALTITUDE (FT)	AVG DIT (KC)	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
DE	1338	100 1 (MID)	5140	4.5	GEAR UP	CRUISE
DE	1340	100 2 (MID)	4740	7.0	GEAR UP	CLIMB
A	1330	100 1 (MID)	4780	6.5	GEAR DOWN	DESCENT
T	1320	101 2 (MID)	5600	1.5	GEAR DOWN	DESCENT

CORRECTION TO BE
ADDED (KNOTS)

CALIBRATED AIRSPEED (KNOTS)



APPENDIX F. DEFINITIONS, ABBREVIATIONS, AND SYMBOLS

This list includes most of the symbols used in this report. However, certain portions of the report use special or unusual abbreviations and symbols. The meaning of these is made clear in the text of the report and, when that is the case, the abbreviation or symbol will not be found in this list. Also, certain symbols have more than one meaning; however, the context should make the meaning clear.

<u>Symbols and Abbreviations</u>	<u>Definitions</u>	<u>Unit</u>
b	Wing span	feet
C_{Do}	Minimum coefficient of drag of the propeller-feathered drag polar	--
C_D	Coefficient of drag	--
$C_{D_{BL}}$	Base-line coefficient of drag	--
$C_{D_{PF}}$	Powered flight coefficient of drag	--
C_p	Coefficient of power	--
C_L	Coefficient of lift	--
Cont	Continuous	--
D	Drag	--
e	Oswald's span efficiency factor	--
f	Equivalent flat plate area	ft ²
g	Acceleration of gravity	ft/sec ²
H_D	Density altitude	feet
H_{p1}	Indicated pressure altitude	feet
H_p	Pressure altitude	feet
H_{pic}	Instrument corrected pressure altitude	feet
L	Lift	pounds
MAC	Mean aerodynamic chord	--

<u>Symbols and Abbreviations</u>	<u>Definitions</u>	<u>Unit</u>
Max	Maximum	--
MCP	Maximum continuous power	--
Min	Minimum, minute	--
N _p	Propeller speed	rpm
NU	Nose up	--
ND	Nose down	--
OAT	Outside air temperature	°C
p	Roll rate	radians/sec
P _a	Ambient pressure	in. of mercury
P _o	Standard-day, sea level pressure	in. of mercury
Psi	Pounds per square inch	lb/in. ²
q	Dynamic pressure	lb/ft ²
ref	Referred, reference	--
R/C	Rate of climb	ft/min
S	Wing area	ft ²
SHP	Shaft horsepower	--
SL	Sea level	--
S/N	Serial number	--
STD	Standard	--
T _a	Ambient air temperature	°C
T _C	Coefficient of thrust	--
T _i	Indicated air temperature	°C

<u>Symbols and Abbreviations</u>	<u>Definitions</u>	<u>Unit</u>
T	Thrust	lb
T _{ie}	Instrument corrected on temperature	°C
THP	Thrust horsepower	HP
T _o	Sea-level, standard-day static temperature	°K
V _{cal}	Calibrated airspeed	knot
VHF	Very high frequency	--
V _i	Indicated airspeed	knot
V _{ic}	Instrument corrected airspeed	knot
V _T	True airspeed	knot
V _{MC}	Airspeed for minimum control	knot
V _S	Stall airspeed	knot
V _H	Maximum airspeed for level flight	knot
V _{MO}	Maximum operating airspeed	knot
V	True airspeed	ft/sec
W _a	Engine airflow	lb/hr
W	Weight	pounds
°C	Degrees Centigrade	degrees
°F	Degrees Fahrenheit	degrees
°K	Degrees Kelvin	degrees
Δ	Difference	--
ΔC _D PF-BL	Difference in coefficient of drag due to thrust effect	--
ΔV _{PC}	Airspeed position error correction	--

<u>Symbols and Abbreviations</u>	<u>Definitions</u>	<u>Unit</u>
ζ	Damping ratio	--
θ	Temperature ratio, descent angle	degrees
δ	Pressure ratio	--
σ	Density ratio	--
ρ	Air mass density	slug/sec ³
ω_d	Damped natural frequency	radians/sec
ω_n	Undamped natural frequency	radians/sec
α	Angle of attack	degrees
ϕ	Roll of bank angle	degrees
η_p	Propeller efficiency	--
ϕ/β	Roll-to-yaw ratio	--
dh/dt	Tapeline rate of descent	ft/min
π	3.14159	--
$\eta_{in.}$	Inlet duet efficiency	percent

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